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ENVIRONMENTAL IMPACT STATEMENT
FOR THE
PROTOTYPE OIL SHALE LEASING PROGRAM

Section 102(2)(C) of the National Environmental Policy
Act of 1969

Prepared by
U. S. Department of the Interior

June 1971

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Prepared by
U. S. Department of the Interior

June 15, 1971

INTRODUCTORY NOTE

THIS DOCUMENT IS A DRAFT ENVIRONMENTAL IMPACT STATEMENT WHICH IS BEING PREPARED PURSUANT TO SECTION 102(2)(C) OF THE NATIONAL ENVIRONMENTAL POLICY ACT OF 1969. IT PROVIDES A REGIONAL OVERVIEW OF THE EXPECTED ENVIRONMENTAL IMPACT OF A PROTOTYPE OIL SHALE LEASING PROGRAM. HOWEVER, TO FULFILL THE INTENT AND PURPOSE OF SECTION (102)(2)(C), ADDITIONAL DETAILED DATA ARE NEEDED CONCERNING THE SPECIFIC SITES NOMINATED FOR LEASING.

NOT ALL THE INFORMATION NEEDED FOR THE PREPARATION OF A COMPLETE DRAFT STATEMENT IS AVAILABLE AT THIS TIME FOR, AMONG OTHER REASONS, THE TRACTS WHICH WOULD BE OFFERED FOR LEASING IN THE PROTOTYPE PROGRAM, IF ONE WERE INITIATED, ARE NOT NOW KNOWN. DATA CAN ONLY BE DEVELOPED BY STUDIES OF THE EXISTING SURFACE CHARACTERISTICS AND BY CORE DRILLING TO DEFINE THE LOCATIONS OF THE OIL SHALE RESOURCE, ITS GEOLOGIC (INCLUDING HYDROLOGIC) CHARACTERISTICS, AND THE PHYSICAL AND CHEMICAL PROPERTIES OF THE RESOURCE AND ADJACENT STRATA. KNOWLEDGE OF THE SPECIFIC TRACTS THAT WOULD BE LEASED IS ESSENTIAL BEFORE THE TYPE OF MINING TO BE EMPLOYED AND ITS EFFECT ON A SPECIFIC LOCALE CAN BE EVALUATED AND THE ENVIRONMENTAL IMPACT OF THE PROGRAM FULLY ASSESSED.

THIS DRAFT STATEMENT IS BEING PUBLISHED IN INCOMPLETE FORM AT THIS TIME SO THAT ALL INTERESTED PARTIES MAY KNOW THE REGIONAL ENVIRONMENTAL IMPACT OF THE PROPOSED PROGRAM AND THE ALTERNATIVES NOW BEING CONSIDERED. ANY COMMENTS

RECEIVED ON THIS DRAFT STATEMENT WILL BE GIVEN CAREFUL CONSIDERATION. WHEN SUFFICIENT ADDITIONAL INFORMATION HAS BEEN OBTAINED BY THE DEPARTMENT TO PREPARE THE NECESSARY SUPPLEMENT TO THIS DRAFT ENVIRONMENTAL STATEMENT (PROBABLY IN THE SPRING OF 1972), THE DEPARTMENT WILL PUBLISH SUCH A SUPPLEMENT AND WILL THEN SOLICIT COMMENTS FROM FEDERAL, STATE, AND LOCAL AGENCIES AND THE PUBLIC ON THE DRAFT STATEMENT AS SUPPLEMENTED. AT THAT TIME, THE DEPARTMENT WILL ALSO HOLD HEARINGS AT WHICH ALL INTERESTED PARTIES MAY SUBMIT THEIR VIEWS.

CONSEQUENTLY, IT MUST BE RECOGNIZED THAT THIS DRAFT ENVIRONMENTAL IMPACT STATEMENT WILL BE EXPANDED AND THAT ANY FACT OR CONCLUSION CITED IN THIS STATEMENT MAY BE MODIFIED, IN WHOLE OR IN PART, BY SUPPLEMENTAL INFORMATION ACQUIRED BY THE DEPARTMENT IN THE COURSE OF CORE DRILLING AND STUDY OF THE PROPOSED PROGRAM.

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I. Abstract

Oil shale is a natural resource occurring largely on public lands that contains vast amounts of solid organic matter that can be converted into oil. To stimulate development by private enterprise, a program to lease a limited amount of this public resource is under consideration.

This program would be a "prototype" since it seeks to establish a new cooperative effort between the private and public sectors to assess the complex relationship between the development of oil shale and environmental maintenance. By necessity, existing technology would be modified and new technology developed both for extracting the oil and for reducing the environmental impact.

The foreseeable environmental impacts of the proposed program include changes in the existing uses of about 0.5 percent of the land within the oil shale regions. No degradation of the existing water quality is expected and maintenance of the air quality within strict standards is attainable. The proposed program would also result in increased population and industrialization which would affect the area and its resources. Socio-economic changes involved in urbanization would occur.

It is the purpose of this Draft Environmental Impact Statement to explore the net effect of development prior to reaching a decision concerning program implementation. Comments by the public will be of major importance in the ultimate decision concerning this proposed prototype oil shale leasing program.

II. Introduction

About 25,000 square miles (16 million acres) of oil shale resources underlay the States of Colorado, Utah, and Wyoming - one of the largest hydrocarbon deposits in the world. The highest grade deposits[1/] occur over an area of 17,000 square miles (11 million acres) and contain an estimated 600 billion barrels of oil. Recovery of even a fraction of this resource can significantly supplement our growing consumption of oil which now totals slightly over 5 billion barrels each year.

Of the total oil shale resource, about 80% lies beneath public lands administered by the Department of the Interior. Any actions by this Department will, therefore, have direct and important bearing on the timing and manner of oil shale development.

A prototype oil shale leasing program is under consideration[2/] to stimulate the development of commercial technology currently in the pilot plant and semi-works stage of development. There are two primary goals of the prototype leasing program: (1) to stimulate the development of commercial oil shale technology to ensure that oil from shale will be available as a future domestic supply option when needed; and (2) to do so in a manner that will ensure the minimum possible impact on the present environment while providing for the future restoration of the immediate and surrounding affected area. The program could also provide the necessary expertise to manage the oil shale lands in the most

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[1/] Those deposits at least ten feet thick, averaging 25 or more gallons per ton.

[2/] For a complete description see: U.S. Department of the Interior, Program Statement for the Proposed Prototype Oil Shale Leasing Program, Washington, D. C., June 1971.

efficient manner so that this Nation may continue to enjoy an adequate and dependable supply of energy at the lowest cost consistent with other national goals.

The method proposed to achieve the goals of the prototype program is to make available for private development up to two leases in each of the three oil shale states. Each lease, by law,[1] can total no more than 5,120 acres, or a maximum of 30,720 acres if all of the leases were developed. The total area that may be affected under this prototype program represents about 0.5 percent of the lands believed to be commercially valuable for oil shale development.

Although it encompasses only a small area, the scope of the program is large enough to achieve the program goals while providing practical experience needed to refine administrative procedures. Oil shale development, however, would have an environmental impact. This environmental impact statement, therefore, has been prepared in accordance with the requirements of Section 102(2)(C) of the National Environmental Policy Act of 1969.[2] This section of the Act requires a detailed statement as to:(1) the probable environmental impact of the proposed program; (2) the probable adverse environmental effects which cannot be avoided; (3) any irreversible and irretrievable commitment of resources which would ensue should the program be implemented; (4) the relationship between local short-term uses of the area in question and the maintenance and enhancement of the long-term productivity;and (5) alternatives to the proposed program.

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[1] See Section 21(a) of the Mineral Leasing Act of February 28, 1920, as amended (30 U.S.C.§§ 241(a)).

[2] See 42 U.S.C. §§ 4332(2)(c)(Supp.V, 1965-69).

The basis of this environmental impact statement is provided by Departmental and Interagency studies, and by the States of Colorado, Utah, and Wyoming. This thorough seven-month study of lease sites, typical of those that may be nominated for development under this proposed prototype leasing program, involved more than 150 professionals with diverse backgrounds drawn from various Federal and State agencies, research foundations, universities, independent conservation groups, and inudstrial firms. The State reports are available[1/] and contain extensive information on the expected environmental impact and controls that must be applied as oil shale leases are developed commercially. The reader is invited to review these reports as a supplement to the information presented in this document.

Under the provisions of the proposed program, detailed environmental impact studies will be conducted of the actual sites nominated for leasing. Only those sites that can adequately satisfy the rigorous environmental criteria established for this prototype program would be offered.

A. Detailed Environmental Studies

1. Prior to Program Commitment - Core drilling operations and lease nomination will identify the areas of greatest commercial interest and aid in directing efforts aimed at assessing environmental impacts. The data developed through coring is required to

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[1/] Copies of the individual reports prepared for the Department of the Interior by the States of Colorado, Utah, and Wyoming are available through the Geological Survey Map Information Office, Room 1039, General Services Building, Washington, D. C. 20242, at $2.00 per copy, per State. Please specify which State report is desired. Additional copies of this Draft Environmental Impact Statement and the Program Statement for the Prototype Oil Shale Leasing Program may also be purchased through the same office at $2.00 per copy per report.

define the location of the oil shale resource, its geologic (including hydrologic) characteristics, and the physical and chemical properties of the resource and adjacent strata.

Among the factors to be considered are existing and anticipated land uses, the indigenous plant and animal life, and aquatic resources of the proposed site and surrounding area. The site location relative to known historical, archeological, and scenic attractions will also be assessed.

The type of mining-waste disposal system(s) most likely to be used if the proposed site were developed will then be evaluated in relation to the actual characteristics of the area. Where there is a distinct probability that operations would have an unacceptable impact on existing resources, or where there are apparent unacceptable risks, nominated sites will be eliminated from subsequent considerations in accordance with the criteria for lease rejection clearly enumerated in Chapter IV.

These detailed environmental studies will establish prevailing conditions against which to measure actual environmental impact. The studies will be conducted by the Department of the Interior in consultation with the Governors' Panels of the States of Colorado, Utah, and Wyoming.

Environmental information developed for each site will be published as a supplement to this 1971 Draft Environmental Impact

Statement for the Prototype Oil Shale Leasing Program and be subjected to public review.

2. Following Leasing - A primary objective of this prototype program would be to compare the actual environmental impact with the projected impact. Air and water quality would be monitored by the site operator and assessments of the environmental consequences would be made by both the operator and Government representatives. The impact on other resources including agriculture, fish, wildlife, recreation, and general aesthetics would also be assessed. Actual plant-site development would be compared with the plans of the local governments, in order to assure effective coordination.

   Operations must meet the specified standards. Failure to comply in a reasonable time could result in cancellation of the lease. Where operations cause unforeseen environmental effects, operating procedures will be changed consistent with the terms of the lease to control such effects to the maximum extent possible. Additional costs incurred by the operator in making such changes could be credited against royalties due the Government. Such credit has been considered only in connection with the proposed prototype oil shale leasing program so that unanticipated environmental protection expenditures involved in the development of this resource would not be placed inequitably on the lessee. Additional program provisions to prevent and mitigate environmental damage are detailed in Chapter IV.

III. Probable Environmental Impact of Proposed Prototype Leasing Program

The 11 million acres of the richest oil shale lands that lie in the three-State region of Colorado, Utah, and Wyoming are located in a sparsely settled, semi-arid to arid region of moderately high elevation.[1/] Physiographically, the region ranges from the high, dissected plateau of the western slope of the Colorado Rockies, to the sparsely vegetated, arid plains in Wyoming. It is drained by Upper Basin tributaries of the Colorado River. Geologic uplift, stream erosion, and varying degrees of resistance of rock layers to weathering control the land forms. Soil development ranges from essentially none to moderate.

The region is predominantly rural in character. Overall average population density is approximately three people per square mile. The nearest major cities are Denver, Colorado, and Salt Lake City, Utah, each more than 200 miles from the nearest oil shale area in those States.

The major existing industries are oil and gas production, limited uranium and vanadium production in Colorado and Utah, and oil, natural gas, sodium (trona) and coal production in Wyoming. Agriculture, livestock raising, and some recreational activities are also pursued in the region.

The environmental effects encountered as the prototype industry develops would be essentially the same as those faced if a full-scale

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[1/] A more detailed description of the resources and characteristics of the oil shale lands is given in Appendix A.

industry grows and matures. The prototype stages of shale development would thus permit industry and concerned private groups, and the appropriate Federal and State agencies to: (1) further assess the nature and extent of these environmental effects; (2) acquire knowledge and skills in monitoring and control; and (3) determine more accurately the costs of environmental protection. All of these experiences would be directly applicable to any later stages of industry expansion. Therefore, it is expected that a future oil shale industry would be aware, from its initial stage of operations, of nearly all the environmental problems that must be resolved. Further, it is expected that techniques would be developed to preserve the environmental integrity of the area. The information gained by this program will be used to assess the environmental impact of a mature industry prior to the issuance of any leases other than those associated with this program.

Details on the various current operations for processing of oil shale are presented in Appendix B. The major steps include mining, crushing, conveying, retorting, product recovery and upgrading, byproduct recovery, and spent shale disposal. If in-situ processing were to become feasible, several of these steps (mining and waste disposal) would be eliminated. In the section on environmental impact to follow, it is assumed, in the interest of brevity, that the reader is either familiar with the technology involved, or can refer to Appendix B.

A. Impact on Land

1. Core drilling

Coring is the process of obtaining fresh subsurface samples of a rock formation using rotary drilling and coring equipment. To date, about 340 core samples of oil shale have been obtained from 225 locations in Colorado, 70 in Utah, and 45 in Wyoming. Equipment capabilities, personnel, and the amount of surface areas required for typical coring operations in the three State area are as follows:

	Large rig	Small rig
Equipment capabilities, feet	6,000-8,000	500-4,000
Personnel required, number	10-15	4-6
Amount of surface area disturbed, acres	10-15	3-5

The diameter of the core ranges from 1 7/8 inch for the small rig to 4 - 7½ inches for the large rig. Length of the core sections vary from 10 to 60 feet. Air is usually preferred as the coring fluid, but water and/or drilling mud is also used.

After the cores have been extracted, well logs are produced which give valuable information about the resource characteristics. A typical oil shale logging program would include: (1) electric - spontaneous, (2) gamma ray-neutron, (3) density, (4) caliper, and (5) sonic logs.

The cores extracted from the oil shale are shipped to various laboratories for detailed analysis of their chemical and physical properties. Nearly 80 percent of all oil shale cores have been examined at the Bureau of Mines Energy Research Center in Laramie, Wyoming.

Core holes which encounter water of usable quantity and quality have the potential for use as wells. The useful life of such a well may continue for a number of years following coring. If it flows artesian water, the normal practice is for the Bureau of Land Management to assume responsibility. If the well does not produce fresh water, it is often desirable to leave it open for use in further sub-surface studies, e.g. surveys of temperature, water quality and levels, and seismic activity. Abandoned wells are plugged according to U. S. Geological Survey operating regulations.[1/] Ground disturbed in the operations (up to 15 acres) is restored to a condition as nearly like the surroundings as possible, and is reseeded according to the specifications included in the authorization for coring on public lands.

During the process of obtaining nearly 340 cores from wells drilled in the three oil shale States, no significant environmental impact has been observed.

2. Surface Processing[2/] - Oil shale development as the consequence of the proposed prototype program may require large amounts of shale to be mined, processed, and disposed. Several acceptable technical options are available for each phase of these operations, and probably no single system will dominate initial development of this resource.

[1/] See 30 CFR 231.8

[2/] In-situ processing of oil shale is discussed below in Section III-G.

Total oil production from the leases to be offered for development may conceivably reach 200,000 barrels per day about 6 years following the granting of such leases. Production beyond this time would be controlled by resource availability, technologic progress, the cost of developing other liquid hydrocarbons, and current product values. Present knowledge indicates the leases offered under the proposed program would support a total output of no more than 400,000 barrels per day. The Department will be better able to evaluate this potential output following coring and lease nomination.

To support 200,000 barrels per day total production, about 300,000 tons per day of oil shale would have to be mined, crushed, and retorted, and the disposal of over 260,000 tons per day of processed waste shale would be required. The land requirements for a single operation typical of those that may be used in actual production will vary significantly, depending on the processing system to be used. These requirements are tabulated in Table III-1 and discussed in the sections which follow.

a. Mining and Waste Disposal - Mining and waste disposal can be conducted either at the surface or underground. However, disposal of spent shale after retorting is directly related to the type of mining used. In addition, depending on the retorting method employed, the spent shale may vary in particle size from a fine powder to lumps which are up to 3 inches in diameter. As discharged from the retort it will normally be

Table III-1 Land Requirements; Oil Shale Surface Processing.
(50,000 barrels per day operation)

Function	Land Required, acres
Mining and Waste Disposal	
Surface Mine[1]	
Mine Development	200 to 250 per year
Temporary Storage; overburden[2]	400 (total)
Temporary Storage; spent shale[2]	100 to 150 (total)
Permanent Disposal[2]	56 to 80 per year
Mining and Waste Disposal	
Underground Mine	
Mine Development (surface facilities)[2]	10 (total)
Permanent Disposal	
No return of wastes[2]	56 to 80 per year
60 pct. return of wastes	
First 3 years[2]	96 (total)
After first 3 years[2]	22 to 32 per year
Facilities[3]	100 (total)
Off-site requirements[4]	100 to 200 (total)

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[1] Area affected depends on the thicknesses of the overburden and oil shale.

[2] Assumes a 50,000 barrel per day shale oil production rate, 25 gallons per ton oil shale, and a disposal height of 250 feet.

[3] Facilities include shale crushing and storage, retorting, oil upgrading and storage, and related parking, office, and shop facilities.

[4] Includes access roads, power and transmission facilities, water lines, and oil pipelines; actual requirements depend on site location. A 30 foot right-of-way for roads or utilities require a surface area of about 4 acres for each mile.

dry, but water (10% to 20% by weight) may be used on the disposal piles to reduce dusting and aid consolidation. Transport to the disposal area may also be accomplished by a water slurry system. Potential water and air pollution problems associated with waste management are considered in subsequent sections of this chapter; only the impact on the land is considered herein.

(1) Surface - Open pit mining involves removal and disposal of the overburden to expose the oil shale for extraction. The quantity of overburden material significantly affects the economics and time-span involved in reaching production. Current surface mining techniques using existing large-scale equipment could be expected to permit mine development at relatively low costs, although waste disposal and land restoration costs may be greater than similar costs for underground operations.

Land required for actual mining activity for a 50,000 barrels/day operation (Table III-1) would directly involve from 200 to 250 acres per year, or 4,000 to 5,000 acres over a 20-year life of an operation.

During early years of an open-pit development, overburden disposal would be off-site, in a temporary disposal area. After 6 or more years, it would be possible to begin disposing of overburden in the pit.

Mining of 25 gallon/ton oil shale at a 50,000 bbl/day open-pit operation would require temporary off-site disposal of up to 150 million cubic yards of overburden before pit return could begin. However, by carefully selecting the disposal site and applying contouring techniques to control surface drainage, the area of land affected could be restricted to 400 acres. Revegetation could begin in the early years and be continued until pit return of overburden was initiated. Following this, restoration of the disposal site could begin.

The processed spent shale, like the overburden, must initially be stored in an area away from the mine site. Return of the stored processed shale to the pit could begin after pit development is completed (about 6 years). During the storage period, until initiation of the procedure of returning spent shale to the mine, some 100 acres[1/] of land surface would be required for temporary dump space, or 150 acres of equivalent canyon space.[2/]

During full scale operations, 75,000 tons per day of processed spent shale (60,000 cubic yards) would be produced at a typical plant. At full capacity, such a plant would require 56 acres of spent shale storage area

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[1/] This assumes that production at full 50,000 bbl/day capacity is not reached until the end of the third year after start-up.

[2/] Includes the canyon floor plus the sides which would be covered.

per year if the surface dump were 250 ft. in depth; or about 80 acres per year of equivalent space if a dry canyon in the shale area were filled to the same depth.

During any open-pit mining operation, the topography will be altered and the environment will be disturbed. The actual area affected will be determined by the thickness of the overburden and oil shale, the mining plan, and the rate of development. Up to 5,000 acres could be involved, and this would be increased about one-third if the waste material is not returned to the pit. In the long-term, open pits refilled with overburden and processed spent shale could be revegetated and restored to a reasonable approximation of their original state.

(2) Underground - The room-and-pillar method of underground mining has been extensively tested. Using this method, a maximum of about 75 percent of the shale could be removed. The remainder is left as pillars to prevent surface subsidence. This type of mining, with most operations underground, requires only about 10 surface acres. However, the method and location of spent shale produced by retorting must be considered. Two methods are available for waste shale disposal: (1) total surface disposal, or (2) a combination of surface disposal and return of the waste to the underground voids left by mining.

Total surface disposal would require the same amount of land as needed for open pit mining (56 acres to 80 acres per year). This acreage requirement can be significantly reduced by disposal of the waste material in the mine. Processed spent shale, however, has a lower density than the original raw shale and occupies a greater volume than the original rock in place. Therefore, only part of the waste could be returned to the mine. Even with compaction of the waste it is estimated that only 50 to 70% could be returned underground.

If an average of 60% of the waste is returned to the mine, the surface disposal area required is reduced to 40% of that previously described. For a 50,000 barrel per day plant operating at capacity, the required surface disposal area is reduced from 56 acres to 22 acres per year, or approximately 32 acres per year of equivalent canyon space. During the initial operation at any lease site, while the underground mine is being developed, all waste would temporarily be stored above ground until sufficient mined-out space for disposal was available. For the 3-year period needed to reach full capacity, the required surface disposal area would approximate a total of 96 acres.

A maximum of 2,000 surface acres would be affected over a 20-year period by an underground mine development of the size indicated in Table III-1.

b. Surface Restoration - Restoration operations would include contouring to blend with surroundings; construction of conduits, retaining dikes and terraces to prevent erosion, control surface run-off, prevent downstream contamination, and provide paths for normal water flow; protection of any natural streams; and revegetation.

Revegetation is initially needed for watershed protection. It has been experimentally demonstrated that vegetation can be grown on processed oil shale with adequate reseeding, fertilization, and watering. For example, Kentucky blue grass western wheat and crested wheat have been successfully grown, and initial findings indicate that, once established, some of these species may become permanently established without further maintenance. Further investigations would be needed to develop and improve methods for stabilizing and accelerating vegetative growth.

A longer range vegetation goal would be the re-establishment of the natural plant community, or suitable replacement, to serve as wildlife food and cover. Native sage, Englemann Spruce, and juniper have been successfully transplanted to processed oil shale. However, a significant body of research experience indicates that re-establishment of the fuller range of native browse and cover species, such as mountain mahogany, shadbush and bitterbrush, is difficult and time-consuming. Additional investigation is needed in this area.

3. Facilities and Off-site Land Requirements - The raw shale is conveyed to a crushing plant and then to a retorting plant, where it is heated to yield shale oil, which must than be upgraded to pipeline quality. The acreage required for a modern, well-engineered processing plant is considerably less than is needed for the mining operation. The 50,000 barrel per day plant (Table IV-1) would be expected to occupy somewhat less than 100 acres for the crushing, crushed shale storage, retorting, oil upgrading, oil storage and related parking, office and shop facilities. The retorting plant itself would require 5 to 10 acres of this total.

Off-site requirements for each plant would have an effect on the surrounding area to some degree. Access roads, power-and-gas-transmission facilities, water lines, and oil pipelines would have to be constructed. Because only one access road would be required for each of the 6 sites, relatively little land would be needed for road-building, although underpasses and suitable fencing may be required to reduce interference with wildlife migration patterns.

New power lines should be constructed in accordance with the environmental criteria outlined in recent Federal publications.[1/] Natural gas lines, if required, would be buried underground,

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[1/] See particularly Department of the Interior, Department of Agriculture Document No. 0-4-4-932, Environmental Criteria for Electric Transmission Systems, 1970 .

using existing techniques for filling excavations, and reseeding of the right-of-way. Water supply lines would be buried, employing similar practices.

Shale oil from the processing plant sites would be moved to refinery centers via connecting pipelines from the sites to existing transcontinental pipelines. These 10 to 12 inch connecting lines could be constructed in some cases using existing rights-of-way to ensure minimum surface disturbance, with appropriate revegetation and positive maintenance to prevent leakage. However, some isolated and localized leaks may eventually occur.

It is not possible at this time to accurately estimate the total off-site surface requirements, since these are directly related to the individual site location. From 100 to 200 acres per site will normally be required, as indicated in Table III-1.

4. Urban Requirements - During the first 6 years of the prototype leasing program, total production on the leases offered for development in the three States may reach 200,000 barrels of shale oil per day. Cumulative construction and operating employment (including urban support personnel) would approximate 18,000 people by the end of this period. The total population including families, in the entire shale region could increase by some 47,000 people, resulting in increased urbanization of the area.

This incresed urbanization would be distributed in the three States of Colorado, Utah, and Wyoming, in proportion to the production developed on each of the leases issued. Because the shale region is now predominantly rural, urbanization would inevitably have an environmental impact on the area.

It is difficult to quantitatively predict the cumulative effects of this urbanization. In general, most new permanent urban construction probably would be in existing population centers at or near the shale lease sites in each State. Temporary employment for plant construction would be substantial (perhaps 50% of the population increase would be in this category), creating need for "temporary" housing (trailer villages, for example) in addition to permanent housing. Expansion of support facilities (business districts, hospitals, schools, and other) would also result along with an accompanying environmental impact on the land. A few new small communities may appear, but are likely to be scattered.

5. Summary - If all six leases proposed for the prototype program were developed, approximately 30,000 acres of land would be affected by oil shale operations, with perhaps an additional 20,000 acres affected by off-site land requirements, including urban needs. About 50,000 total acres would be required, or about 0.5 percent of the total area believed to be commercially valuable for development.

B. Impact on Water Resources

1. Water Availability - Water for oil shale development would be supplied from the amount allocated to the States of Colorado, Utah, and Wyoming under the Upper Colorado River Compact. It has been estimated by the Bureau of Reclamation[1] that up to 5.8 million acre-feet per year are available for Upper Basin depletion (i.e. consumption). Studies have indicated[2] that some 200,000 acre-feet annually are potentially available for oil shale development in both Wyoming and Utah; and from 86,000 to 456,000 acre-feet annually in Colorado.[3]

A prototype leasing program which reached a total oil production of 200,000 barrels per day at the end of 6 years would have a water requirement of approximately 30,000 acre-feet annually, of which 12,000 to 19,000 acre-feet would be consumed and the balance returned to the Basin's streams. Adequate water would be available in the three States for the proposed prototype oil shale leasing program. Indeed, an adequate quantity of surface water would appear to exist for the growth of a full-scale industry of several million barrels per day.[4]

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[1] Upper Colorado River Basin Compact, Senate Report 408, 90th Congress, 1st Session, July 26, 1967, p. 17.

[2] For complete analysis of water demand and availability, see U.S. Department of the Interior, Prospects for Oil Shale Development, Colorado, Utah, and Wyoming, Washington, D. C., 1968, pp. 99-105.

[3] The actual amount in Colorado is dependent upon the interpretation of certain pending non-oil shale water commitments.

[4] A one million barrel per day industry would require approximately 145,000 acre-feet net diversion annually.

Processing saline minerals associated with some of the deep oil shales (in Colorado especially) to recover soda ash and alumina would create an additional water requirement. The future of such operations is still technically indeterminate, so no attempt has been made to quantitatively assess these additional demands on water resources.

In addition to oil, as much as 10 gallons of water per ton of shale could be produced in the surface retorts. This water would contain dissolved saline and organic compounds and could be used to moisten the waste shale to prevent dust problems. However, it would require treatment prior to use to remove hydrocarbons and malodorous compounds, and perhaps dissolved minerals.

Large quantities of natural ground water occurs in leached zones of the deep oil-shale areas, but the location, composition and movement of such waters have not been well defined. These aquifers may contribute substantially to the overall water supply available to satisfy requirements for oil shale development.1/

2. Water Quality - The nature of the foreseeable problems associated with water quality would depend largely upon the mineral characteristics of the processed shale and the method of disposal. All foreseeable problems, outlined below, are controllable with

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1/ In one recent study it was estimated that a 640 acre open-pit mine in northwestern Colorado could produce an average of as much as 20,000 acre-feet of water per year. U.S. Geological Survey, Digital Computer Modeling for Estimating Mine Drainage Problems, Piceance Creek Basin, Northwestern Colorado, open file, 1970.

present technology. Under the terms of the proposed prototype leasing program, the goal is to permit no degradation in the quality of the naturally occurring waters of the oil shale region.[1] The use and disposal of water would be monitored by the appropriate Federal and State agencies involved.

The major potential sources of contamination of waters would be the spent shale disposal operations, retorting, partial refining of shale oil, and saline mineral extraction processes. These potential problems are discussed below.

a. Sediments - Improper handling of overburden or spent shale in surface disposal operations could create windblown dust or permit sediments to be carried from the waste piles by surface waters. The extent of this problem would depend largely on the nature of the material being handled and how it is treated before or during the disposal process. At present, either wetting spent shale piles, followed by compaction and revegetation, or perhaps disposal as a slurry, followed by dewatering would appear to be feasible methods of controlling dust and sediments.

Design concepts for controlling sediment problems may include canals and culverts to carry runoff water around and/or under the disposal site. Protection against flash floods common to the area could be provided by upstream dams and canals to intercept the storm runoff from the waste pile; retaining dikes and terraces could be used to prevent erosion. These measures, plus adequate revegetation could reduce the sediment yield to the streams to an amount less than the same areas contribute under natural conditions.

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[1] It should be noted that the Colorado River is now partially contaminated naturally by saline minerals and sediments. The control measures needed to achieve the proposed program's water quality goal could help reduce natural erosion in localized situations. For analysis, see: U. S. Department of the Interior, Quality Water and the Colorado River Basin, Progress Report No. 4, January, 1969.

b. Leaching - Mineral leaching by water precolating through the waste piles is not anticipated to be a significant problem, since compacted and moistened retorted shale has been shown in experimental tests to be of low water permeability. Natural cementation also takes place over relatively short time periods, particularly when the spent shale has been moistened and compacted, tending to minimize surface leaching and sediment runoff. No tests, however, have been conducted on large volumes of materials such as would be continually deposited during routine operations, since it is extremely difficult to simulate field conditions on a small scale.

The leaching of minerals would depend upon the characteristics of the waste shale, the rate of disposal, the amount and type of precipitation, and the rate and depth of surface water infiltration. The rate of wa[illegible] buildup from a typical 50,000 barrel per day plant (from 10 to 20 feet per acre per year) would exceed the buildup of soil moisture from the low annual precipitation (1 to 2 feet per year). Because of this, the water could not saturate the waste material during the emplacement process. To prevent future ground water contamination, however, it may be necessary initially to construct a permanent impermeable floor where the waste material is to be deposited. This barrier would prevent all leach waters from entering underground water systems and would direct percolating waters toward the impoundment dams where they could be controlled.

As mentioned previously, the water produced in retorting probably would be used to wet down the spent shale. If required, these waters could be treated to avoid leaching problems.

Spent shale disposed of in underground mines could be subject to leaching if the mine workings were flooded while active, or became saturated after mining operations ceased. The environmental controls described in the State reports prepared for this environmental study have been shown in similar type operations to be adequate to resolve this potential water quality problem.

c. Underground Waters - Disturbance of ground waters could have an effect on water quality. The extent of this impact, if any, cannot now be accurately predicted. Until more is learned, disturbance of these waters necessarily would imply some risk. However, all operations would be closely monitored. Where it is determined that a disturbance would be hazardous, or there is a distinct probability that a disturbance will be hazardous, operations would be curtailed to the extent necessary to avoid the disturbance, or until the problem is satisfactorily solved.

d. Other Process Wastes - In addition to the effects of mining and spent shale disposal on water quality, consideration must be given to the possible effects from retorting and shale oil upgrading, and any processing of saline minerals.

The treatment of waters produced in retorting has been previously discussed. In addition to these waters, there would possibly be a water slurry produced by a wet scrubbing process used to remove fine dust in gas streams. The slurry from the wet scrubbing could be used to wet spent shale. Water would also be used in the cooling phase of the process, but the amount needed could be kept to a minimum by employing air cooling. Any "sour" water streams produced by accidental contact with oil in final water condensers would be treated by conventional oil refinery methods (e.g. steam distillation, chemical treatment) prior to disposal.

In the shale-oil upgrading process, the principal source of contaminated water would be from steam condensed in the gas-processing facilities, which would contain dissolved organic compounds. This water would be purified by conventional refinery treatment techniques and probably used in processed shale disposal. The water used in the cooling tower also may contain high concentrations of dissolved-salts. Again, this would be conventionally treated and used in shale waste disposal.

Small plants may be required to generate electricity for oil shale processing. Cooling water would contain dissolved solids and could also cause thermal pollution if returned untreated to the streams. These effects can be largely avoided by using this water in processed shale disposal operations.

The principal problems associated with a saline minerals-extraction industry would be those concerned with solids handling in stockpiling the spent shale prior to dawsonite roasting and in disposal of the denuded shale after alumina recovery. In the latter case, approximately 25% residual water will remain after dewatering the spent shale following alumina extraction. This residual water could aid in subsequent disposal employing the solid handling techniques described above.

The roasting of the dawsonite, its subsequent solubilization, carbonation, precipitation, and calcination, and the soda ash recovery operations all involve standard industrial chemical-processing techniques to which existing water antipollution safeguards could be routinely applied.

C. Impact on Air Quality

The principal sources of potential air pollution in a prototype oil shale development would be solid particulates resulting from mining and spent shale disposal operations, dust produced during crushing and retorting operations, process stack gases from retorting, refinery byproduct gases from shale oil upgrading, and any flue gases from electric generating plants or similar processes.

1. Particulates - Potential dusting from surface waste disposal piles, mentioned previously, would be prevented by moistening the material and using disposal and revegetation techniques already under development in field tests. If residue shale were transported in dry form, covered conveyors would be required. In an underground mining operation, it is expected that a majority (up to 70%) of the waste could eventually be returned to the mine, thus reducing potential dust producing surface piles. The shale crushing operation would require enclosed crushing and conveyor facilities wherever possible, and protection of the piles of crushed shale from wind erosion.

2. Process Stack Gases - No critical air pollution problems would be anticipated in connection with handling and utilizing the gases produced in oil shale retorting operations. Regardless of the retorting process, gases would be coproduced with the oil product. The mixture of oil and gas products would be conducted via a closed system from the pyrolysis section of the process operation to a separation and recovery section, in a state varying from true vapor to mist to liquid, depending upon the particular process and its operating conditions. Treatment to recover the maximum amount of oil possible also would remove water and particulate matter. The remaining product gases yield small amounts of sulfur, which may or may not be economically recoverable.

A special situation exists in the case of the ball heater in the TOSCO process, where it has been found that wet scrubbers instead of dry cyclone separators would most efficiently remove solid particulate matter.

During shale-oil upgrading, large quantities of fuel may be burned to supply heat for processes such as distillation, delayed coking, catalytic hydrogenation, and hydrogen production. The products of combustion would contain some oxides of sulfur and nitrogen. The sulfur oxides could be controlled within acceptable limits by the appropriate selection of low sulfur fuel, or by a sulfur-removal stack gas system. Nitrogen oxides could be minimized by design of the combustion unit to avoid the excessive temperatures which lead to the formation of this pollutant.

Any power plants associated with oil shale development would produce stack gases which could be sources of air pollution. Such contamination would be avoided by applying conventional modern utility techniques for removal of particulate matter, and by the control of sulfur and nitrogen oxides emissions through the use of low sulfur fuels, combustion temperatures control, scrubbing, etc. It would be a stated lease requirement that all applicable Federal, State, and community standards for air quality must be met in this phase, as in all other steps in the mining and processing of oil shale during the proposed prototype leasing program.

D. Impact on Fish and Wildlife

Certain areas of the oil shale region provide a habitat with an attractive combination of vegetative, climatic, physiographic, and cultural conditions for nearly 300 species of wildlife, including seven big game species, of which the mule deer is by far the most important. In addition, the region as a whole harbors 3 species of small game, 5 species of fur bearers, and 21 species of non-game mammals. The bird population includes 27 species of migratory waterfowl and shorebirds, 6 species of upland game birds, 24 species of raptors, and many species on non-game birds. Several wild horse herds (about 500 animals total) range over certain portions of the region.

Fishery habitat is limited, and inhabited principally by non-game fish populations. Small trout populations (cutthroat, rainbow, brown) live in headwater areas, and are the principal target of anglers.

A more detailed description of the individual fish and wildlife resources of the principal oil shale basin in the States of Colorado, Utah, and Wyoming is given in Appendix A.

Probable and potential impacts on wildlife and fish are of two general types: localized impacts at and in the vicinity of the actual oil shale operations; and impacts resulting from ancillary urbanization and human pressures. These are discussed in the following two sections.

1. Localized Impacts - If all six leases of the proposed prototype program were issued and developed, approximately 30,000 acres of land would be directly affected by the oil shale installations, along with an additional 20,000 acres for access roads, collection pipe corridors, utility and water lines, and other satellite service facilities. Expressed as a percentage of the three-state oil shale area, the total of 50,000 acres represents 0.5% of the surface land area.

Construction, operations and servicing of plants on the six sites would have both direct and indirect impacts upon the normal behavior and activity patterns of wildlife in their vicinity. The impacts would be localized and include such things as: reduction of food and cover through removal of overburden and surface vegetation for facilities, roads, etc.; and wildlife disturbance from noise of mining and industrial operations.

Oil shale region animal species sensitive to such activities in decreasing order of effect are: mountain lion, bear, elk, mule deer, antelope, sage grouse, blue grouse, and migratory birds. Small mammals, furbearers, and non-game birds would not be significantly affected, although their numbers in the vicinity of oil shale operations would decrease in proportion to disturbance and habitat lost. Much of the project-related habitat alteration described above would be unavoidable, but measures would be taken to minimize and mitigate certain types of undesirable impact. These measures are considered in Chapter IV of this report.

The oil shale areas exhibit limited fishery habitat. However, prototype operations without adequate protective provisions would have the potential to cause stream degradation with subsequent negative effects on fish and other aquatic life populations. Potential sources of degradation include: alteration of terrain and protective watershed cover; increasing water temperature;

mineral leaching from waste piles, and oil leaks or losses from pipelines or at loading areas. Impacts could include: silting of spawning areas, fish-food producing areas, and beaver dams; and toxic and thermal effects. If groundwater use for development and operation resulted in lowering of natural surface water features, such as springs and seeps, adverse impacts would occur upon associated ecological features, including wildlife and fish. Such degradation would be avoided in most cases by: lease site selection to avoid aquatic habitat; installation of equipment, procedures, and plans which would avoid loss of degrading substances to the surface waters; and construction and operating regulations and stipulations which would control polluting substances and keep physical alterations to a minimal level.

The extent of impacts from oil losses, if they were to occur, upon habitat and associated wildlife and fish populations would depend upon numerous factors, including: volume of oil lost, leak location, and weather conditions; the quantity and quality of wildlife and fish habitat affected; timing with respect to organism life history stages; and effectiveness of contingency plans. Most significant impacts would be on aquatic organisms and water-related birds and mammals. Such impacts would be minimized by building oil handling facilities and routing pipelines to avoid the more vulnerable habitats.

2. Ancillary Urbanization and Human Pressures - The 1970 population of the seven-county oil shale region was 117,000. Maximum rate of development of the prototype program would result in an estimated 40% increase in population over the first six years of the program. A full evaluation of impacts of this potential situation upon fish and wildlife would require presently unavailable information upon the locations and size of these developments and activities and the distribution of the projected population increases.

Facilitated access and increasing human habitation and activities across the oil shale area, however, would bring more people in closer contact with fish and wildlife resources. Some species, such as mountain lion, bear, elk, and mule deer, may be incapable of adjusting to the increase in human population activities and developments. Although the declines would not be dramatic, populations of these intolerant species across the oil shale region would be expected to decrease with increasing leasing program-related pressures.

The projected human population growth from the leasing program would result in increased hunting and angling pressure. The more popular game species, such as mule deer, antelope, sage grouse, and chukar partridge, would receive proportionately more of the increased pressure, and this situation would result in higher annual harvests. Effects of increased harvest on individual species would vary, and hunting and fishing quality would be reduced for some species and in local situations. However, for the most part wildlife populations could sustain the increasing hunting pressure for the human population increases expected during the prototype program. Specific game and fish management plans and regulations would be required to adjust or alleviate those local and state problems which would arise from the increased hunting pressure.

E. Impact on Aesthetics, Recreation and Cultural Values

The magnitude of the impact oil shale operations will have on the region's aesthetic, cultural and recreational qualities will depend on the location of the site, its size and the system of extraction and processing as well as the operating practices followed.

The oil shale area is generally remote although little of it can be considered true wilderness. Present access, ranching, mineral extraction activities, and recreational use (principally hunting) would seem to preclude that terminology. "Semi wilderness" may be an appropriate term.

Some stretches of the Green River may qualify as either a wild or scenic river under terms of The Wild and Scenic Rivers Act of 1968. A section of the Green River in Utah is a designated Historic Site.

Flaming Gorge Reservoir and Recreation Area of Utah is the only area which has received National recognition. There are undoubtedly many archeological sites in the region and historic westward wagon trails cross the area in Wyoming.

For the purpose of this evaluation, the aesthetic, cultural, and recreation values associated with the oil shale lands can be grouped into categories which include: scenery, open space, historic sites and trails, archeological sites, and recreational uses. The impact of prototype oil shale development on these broad categories of values is summarized below:

1. Scenery - Mines and processing plants would intrude on natural setting while in existence. However, mines often become major points of interest in themselves. Facilities are expected to be in relatively remote locations, away from highways. Access roads and utility lines or corridors would require careful planning and construction to minimize their visual impact. Following development, proper restoration practices should render the sites scenically compatible with surrounding areas.
2. Open Space - These would be minimally reduced during production, with only about 0.5 percent of the area effected. Widely separated prototype leases and careful site location would tend to reduce the impact.

3. Historic Sites and Trails - Development on or near such land would destroy the value of the sites and would not be permitted. Such sites would be determined in advance and development would be controlled to prevent disturbances in their vicinity. Better access to historic sites and trails is one possible side-benefit of oil shale development.
4. Archeological Sites - No development at or near recognized archeological sites will be permitted. Development at a particular location may uncover other important sites, at which time salvage archeology should reduce the risk of significant losses.
5. Recreational Uses - With the influx of population and improved accessibility, recreational activity in the region would increase. Some increased usage could be sustained, since the recreational potential of the region is largely untapped. There are limits beyond which the recreational quality of the region may begin to decline, for example: More people create demand for facilities (campgrounds, etc.), modifying the present near-primitive camping experience; some increased littering is inevitable with or without facilities. The wildlife population could withstand greater hunting pressure, however, any decrease in the game population accompanied by an increase in hunters would cause the success ratio to fall, perhaps resulting in shorter seasons and reduced bag limits.

   Although better access could open up new areas for recreational uses, increased vehicular traffic (particularly off-road vehicle) could have a very detrimental effect on wildlife and vegetation, and increase erosion. Restriction of these activities may be necessary to preserve the essential character of the region.

6. Summary - Changes in the number and character of population and their activities, resulting from even a prototype oil shale development program, would effect the aesthetic, cultural and recreational aspects of the region. The changes need not necessarily be adverse and with adequate planning and controls prior to leasing and during development, the resources and character of the region can and would be preserved.

F. Impact on Existing Economic and Social Environment

In assessing the impact on the existing social and economic environment, attention has focused on approximately the first six years of the program, if development is initiated and gradually grows to an estimated level of 200,000 barrels per day.[1/]

1. Economic Impact - The prototype phase of an oil shale development program would generate within the region both temporary and permanent new employment, with a concomitant influx of capital. For the purposes of this report, the optimum po-

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[1/] For a detailed analysis of regional economic, social, and community impacts of oil shale development that may approach 1 million barrels per day, see: U. S. Department of the Interior, Program Statement for a Proposed Prototype Oil Shale Leasing Program, 1971, Chapter V; and Ryan, J. J. and Welles, J. G., Regional Economic Impact of a U. S. Oil Shale Industry, Denver Research Institute, University of Denver, July 1966.

tential economic growth has been projected in order to assess the maximum possible impact on the region.

The rate of prototype development, allowing for technologic advancements and the amount of capital invested, would determine the rate of economic expansion. Assuming maximum development, the leases operative at the end of six years would have a cumulative capacity of 200,000 barrels per day. Production, however, would not be equally distributed between leases because of the nature of the deposits at each site and the type of mining and processing operation employed.

Most all temporary employment would be related to the construction of the plants and urban communities. These jobs terminate with the completion of the construction. As long as the prototype program and any resulting industry would continue to develop, shifting of construction personnel would probably take place between the different plant sites. It is estimated that such "temporary" construction employment would gradually increase to 11,000 persons at the end of the six-year period.

All permanent employment would be associated with the routine daily operation of the plants and with urban occupations which provide support services. Permanent employment is expected to increase to 7,500 persons during the first six years.

The total population of the 7-county shale region,[1] including the above employees and their families, would increase by an estimated 47,000 persons during the first six years. The present (1970) population of the seven counties is 117,000 of which 44,000 are employed. Thus, an estimated 40% increase in regional population would result from this oil shale development.

The prototype oil shale program would entail expenditures for plant equipment and new urban facilities; it would also provide a significant influx of money in the form of employee salaries and taxes and other revenues paid to state and local governments.

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[1] Garfield, Mesa, and Rio Blanco in Colorado; Duchesne and Uintah in Utah; and Sweetwater and Uintah in Wyoming.

During the first five years of prototype development, it is estimated that capital expenditures for plant facilities would total $1.0 billion. Because necessary manufacturing facilities do not currently exist within the seven counties that comprise the oil shale region, it is assumed that most plant construction materials would be purchased outside the region. Urban construction required to house the new population would occur mainly in existing towns convenient to plant location. Urban construction would probably take place concurrently with plant construction. Capital expenditures for this purpose would be approximately $175 million over the first six years of the program. Some purchases of urban construction materials would be made within the region, but most would have to be supplied by outside sources.

During the first six years of the prototype program, it is estimated that a total of $440 million would be paid as salaries to construction and construction support employees, and about $190 million to operating and urban support employees. Of this $630 million total, $570 million or 90% of the gross salaries would likely be spent within the oil shale region itself.

Total taxes and public revenues paid over the six-year period under consideration would be about $536 million. These payments would accrue approximately as follows: 67 percent to the Federal Government, 20 percent to the States, and 13 percent to local governments. The Federal share ($360 million) would be derived mainly from income tax payments (corporate and individual) and from the Federally retained portion of the royalties collected. State revenues ($107 million) would be derived mainly from State income taxes, from that portion of the royalty payment rebated to the States, from State use tax on construction materials, and from sales taxes. The local tax share ($69 million) would be primarily property taxes.

2. Social and Community Impacts - The prototype shale leasing program would influence the predominantly rural region by an influx of 47,000 new residents. Presumably the new inhabitants would migrate from more industrialized communities, resulting in an accelerated degree of urbanization for the developmental areas. Changes would occur in life styles, occupational patterns, and current stratification systems. Expansion of business and cultural districts, residential areas, and community amenities (hospitals, libraries, public schools, water and sewage systems, etc.) in existing towns and cities would significantly alter the present community structure. The impact of urbanization would be evidenced by a substantial increase in daily and weekly commuting during all stages of development, intensified during construction periods by the temporary labor needs. A few new population growth centers may appear, but these would likely to be scattered.

There could be some problems associated with inadequacies of existing urban facilities during construction, since at any individual site the temporary population during construction would be more than double the permanent population at that site when construction is completed. If the prototype program were to gradually merge into full-scale industry development, many of the construction employees would move to new installations, or be absorbed, in part, in the permanent employment sector. Capital expenditures for urban development should be self liquidating. The mortgages on private residences would be paid out of wages received by individuals; mortgages on commercial construction would be paid out of business income.

The financing of new public community facilities could be through municipal bonds, to be redeemed from local taxes generated by the program. However, there would be a short time lag between the outlays for new public facility construction and the receipt of the local tax revenues generated by the shale oil plants. This lag would be expected to disappear by the end of the initial six years of the prototype program.

During initial development, several Federal programs could be made available to help support community development. Additional state programs might be needed to guarantee or underwrite local bond issues. Master plans and zoning regulations for many of the counties within the oil shale area have already been prepared or are well along in preparation. There is a need to coordinate these plans for local development with State and Federal plans, in order to ensure that community growth would be both reasonably orderly and ecologically acceptable. As part of its responsibility in stimulating oil shale development, Interior could help bring together the appropriate Federal and State agencies to supplement local community planning in preparation for new industrial development.

G. Impact of In-situ Processing

Thus far, this report has confined its consideration of environmental impact to those problems associated with conventional mining and surface retorting, since these technologies are most fully developed at the present time. An alternate processing technique would involve the recovery of oil from the shale by heating underground, in place. This technique is called in-situ processing and has not been successfully developed or demonstrated on a large-scale to date, although some laboratory and field work has been done. Because the environmental problems associated with in-situ processes are somewhat different than those encountered in mining and surface retorting, it is pertinent to consider them briefly.

Presently proposed heat sources for in-situ recovery include underground combustion, hot natural gas, hot carbon dioxide, superheated steam, hot solvents, and combinations of two or more of these. It is anticipated that conduits for introducing heat underground would be provided by wells, mine shafts and tunnels, fractures created by a variety of techniques, or by a combination of these.

Surface operations for in-situ recovery would be relatively simple, with the absence of problems associated with mining and spent shale disposal. Because of this, disturbance of the original land surface and vegetation would be expected to be slight. Earth moving would be limited mostly to grading for well locations, a plant site, and field roads. It is anticipated that less than ten percent of the land surface over an in-situ recovery project would be affected at any one time. However, the contamination of underground water could pose a problem, since all presently contemplated techniques for such in-situ operations involve establishing permeability by fracturing. The creation of new fractures could change the existing hydrology, thus introducing a new set of problems. For this reason, only limited in-situ operations would be permitted initially, and these would be closely monitored to prevent environmental degradation. Prior to authorization of any commercial in-situ processing, adequate control methods would have to be developed.

IV. Program Provisions Proposed to Prevent and Mitigate Environmental Damage

The probable net environmental impacts of a proposed prototype oil shale leasing program were assessed in the previous chapter. Here the chapter is concerned with the proposed specific provisions of the program which are intended to prevent and/or to mitigate environmental damage.

The comprehensive environmental review conducted during 1970 and early 1971 focused attention on the types of environmental hazards associated with the development of an oil shale industry. To minimize these hazards: (1) certain lands would be excluded from this program; and (2) provisions for protecting the environment would be incorporated into any coring permit or lease.

A. Exclusion of Lands

Oil shale occurring in lands that have a greater value for other uses, or that present associated environmental hazards which cannot reasonably be met or overcome at this time would be excluded from this prototype leasing program. The areas listed below, by State, would be excluded unless adjustments can be made to meet the criteria detailed below in this chapter. Many of the listed areas, although withdrawn or classified as oil shale lands, would not be affected in the foreseeable future, since they do not contain oil shale of current economic interest.

Colorado - All national forest lands; Naval Oil Shale Reserves Numbers 1 and 3;[1] critical fish and game experimental or management areas, including Little Hills Game Experiment Station, Little Snake, Square S Ranch, and Rio Blanco Lake.

Utah - Naval Oil Shale Reserve Number 2;[1] Desolation Canyon and a portion of the Green River designated as an historical landmark; Sand Wash Historical Landmark, a Scenic Overlook on Book Cliffs Mountain Road, Watershed Study Area; a one-half township area which is a critical winter deer range; critical fish and game experimental or management areas, including Utah Herd No. 28A area, Indian Canyon, Starvation Reservoir, Blacktail, Red Creek, Golden Stairs, Avingtaquin Deer Winter Range, and Lake Canyon.

Wyoming - Lands adjacent to or within the Flaming Gorge National Recreation Area, and the Colorado River Storage Project; U.S. Bureau of Mines Oil Shale In Situ Experimental Sites; Seedskadee and Eden Reclamation Projects, including Seedskadee Wildlife Refuge and Migratory Bird Refuge, sodium (trona) mineral area, and a portion of phosphate reserve number 4.

Where oil and gas, trona, coal, or other mineral deposits are present on the public lands in the oil shale leasing areas, provisions would be incorporated in any lease agreement to provide, to the extent practicable, for compatible multiple development.

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[1] Naval Oil Shale Reserves can only be leased by the Department of the Navy.

1. Lease Rejection Criteria

Environmental impact studies would be made of each site nominated under the provisions of this prototype oil shale leasing program. The review would be conducted by the Department of the Interior, after consultation with the Governors' Panels of the States of Colorado, Utah, and Wyoming. Any nominated site would be rejected by the Department if there is a distinct probability that development would have an unacceptable impact on existing resources, or would be likely to present an unacceptable environmental risk. In making these determinations the following adverse effects would be considered:

1. Erosive waste or erosive spent shale piles that cannot be controlled;
2. Siltation of streams or reservoirs;
3. Leaching of deleterious substances from dumps or tailings which would be transported into streams, reservoirs or ground water systems;
4. Introduction of added saline or other contaminants into water courses or ground water aquifers;
5. Creation of disturbed areas not susceptible to revegetation comparable to the existing vegetation in the region;
6. Creation of disturbed surfaces where air currents might be expected to contribute to the degradation of the environment;
7. Emissions generated by processing plants, which would contribute to the degradation of the environment;

8. Loss of critical wildlife or fish habitat, which cannot be avoided, or for which no alternative resolution is available at the present time;
9. Adverse effects on dedicated wildlife refuges or fish hatcheries;
10. Prevention of access by wildlife to essential range, or the restriction of human access for wildlife-oriented recreational purposes, including hunting;
11. Destruction of recognized historic or archaeological sites, or outstanding scenic attractions;
12. Violation of Federal, State, county, and local plans and programs relating to environmental protection and control, except to the extent that the non-Federal programs are inconsistent with Federal Law;
13. Residential development without necessary services, or where necessary services will not be made available; and
14. Any other unacceptable environmental hazard identified during review of tract nominations.

B. Core Drilling Provisions

General and special stipulations pertaining to environmental protection and control, similar to those planned for inclusion in any oil shale lease, are incorporated into each coring permit to be issued by the Department. These will include stipulations concerning field operations, restoration of land, and other provisions appropriate to the exploration. Before operations are begun, a drilling plan will be required for approval by the Department. Such a plan will specify location, drilling method, size of hole, size of core, length and size of casing, safety precautions, and abandonment procedures, as well as a scheduled work performance. Designated Departmental field officials will have access to all operation sites and operational data. Proper completion and abandonment will be carried out under instructions furnished by these field officials and will be completed within one month after expiration of the permit. Failure to comply with the terms and conditions of the permit will be cause for cancellation of the permit and forfeiture of the permit bond.

The permittee will be required, among other things, to: (1) commence drilling operations within one year from the date of issuance of the special land use permit; (2) conduct his operation in such a manner as (a) not to interfere with or endanger operations on any existing or future mineral lease, nor interfere with or endanger other land uses, and (b) to safeguard the water and other natural resource values; (3) comply with all Federal, State, and local regulations or requirements pertaining to these operations, including 43 CFR Part 23 and 30 CFR 231;

(4) post a $5,000 bond with the Department for each special land use permit issued to cover damages that may be caused to the environment or resources, either on-site or off-site, by construction, maintenance, and use of roads or trails, or by other activities conducted under the permit; (5) post a $5,000 bond with the Department for each core hole to be drilled, to assure compliance with regulations (30 CFR Part 231) for drilling and abandonment operations.

C. Lease Provisions

The lease for the proposed prototype program would incorporate a number of features that have been designed to protect the environment. These features are discussed in the following paragraphs; the entire proposed lease has been fully discussed in another document.[1/]

1. Performance Requirements

Actual operations would require approved development plans and acceptable performance by the lessee. A preliminary plan for lease development would be incorporated in the terms of any lease offer made by the Department of the Interior. A detailed plan that includes all proposed development and production operations would have to be prepared on or before the third anniversary of the lease and be approved by the Department prior to the commencement of operations. These plans would include a detailed projected analysis of the amount and types of expected waste materials; the location

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[1/] U.S. Department of the Interior, Program Statement for a Proposed Prototype Oil Shale Leasing Program, Washington, D.C., June 1971.

and extent of the residue disposal areas; the types of vegetation that would be used in land restoration; a time schedule for the restoration process; and a justification that would assure this Department that the operator has designed this disposal-restoration system with the objective of protecting the long-run biotic productivity of the area affected. Annual progress reports would be required and all physical facilities and records pertaining to the operations may be inspected by the Department, concurrent with continuous monitoring of the operation.

The operator would be expected to plan construction and other developmental activities to the extent consistent with Federal Law, in full coordination with the land use, transportation, and other plans of the county, or other local public agency.

2. Standards

All applicable Federal and State standards for protecting the quality of the air and water would have to be met, including without limitation, to the extent applicable, the standards incorporated in Executive Order No. 11574 of December 23, 1970, and the Federal Water Pollution Control Act, as amended (33 USC § 466, et. seq.) (supp. V 1965-1969). The environmental problems anticipated, however, would vary with the methods of mining and processing and with the characteristics of the area to be developed. Therefore, specific environmental safeguards would be tailored for each site and would be incorporated into the lease to be issued. These requirements are designed to provide assurance that the lessee would:

(1) control effluent gases and particulate matter to such a degree as to meet a Federal Standard of Performance as defined in Section 111(2) of the Clean Air Act, as amended; or to the extent consistent with Federal Law, meet standards established by the States of Colorado, Utah, and Wyoming,

(2) control thermal pollution and maintain the quality of surface and subsurface waters in the area to comply with water quality standards established pursuant to the Federal Water Pollution Control Act, as amended; State statutes, and those standards that may be required by Interior,

(3) provide for the stabilization of spent shale and other operational solid wastes that will be stored on the surface, in accordance with mine land restoration regulations of Interior and the States involved,

(4) prevent contamination of the surrounding lands and waterways by soluble materials and silt leached or washed from spent shale and other solid wastes,

(5) prevent release of liquid wastes generated in mining or processing operations to surrounding area and waterways,

(6) control erosion attributable to mining or operational disturbance of the land surface,

(7) preserve and protect other natural and man-made resources within the lease area, including recreational, scenic, and historic values,

(8) protect fish and wildlife and their habitat from damage by mining or surface operations,

(9) provide control for surface subsidence above mined areas in accordance with 30 CFR 231 and lease stipulations for specific tracts, and

(10) restore land surfaces before abandonment to a state commensurate with the original terrain, including revegetation of any solid waste deposits retained on the surface, in accordance with 43 CFR 23.

3. Bonding

A bond would be filed as security that the approved development-restoration plan would be conducted in a manner designed to avoid degradation of the environment and that all other related lease terms would be met. The bond would be for an amount of not less than $500 per acre of the land that is estimated to be affected during the first three-year period of operations; and, in any event, not less than $2000. A similar bond would be filed and maintained for each succeed-three-year period of development. Provision may be made to credit extraordinary environmental costs that may develop after the lease issuance against the royalties otherwise due the Government. This provision has been envisioned specifically for this prototype program so that unanticipated environmental protection expenditures involved in the development of this resource would not be placed on the lessee inequitably.

4. Monitoring of Operations

An important objective of this prototype program is to compare the actual environmental impact with the projected impact. To this end, the air and water quality would be measured and assessments made of the environmental consequences by both the operator and Government representatives. If it is found that the operations do not meet the standards specified in the lease, an immediate adjustment of the operations would be made. Failure to comply in a reasonable time could result in cancellation of the lease. Where operations cause unforeseen environmental effects, operating plan requirements to control such effects would be changed to the maximum extent possible, consistent with the terms of the lease. Additional costs involved in such changes may be credited against royalties, as described above.

The impact on other resources, including agriculture, fish, wildlife, recreation, and general aesthetics, would also be assessed. Additionally, actual plant development would be compared to the plans of the local governments in order to assure effective coordination. Adjustments and changes would be made to control or offset adverse effects pursuant to the regulations, operating plans, and the terms of the lease.

V. Probable Adverse Environmental Effects Which Cannot Be Avoided

Plant construction, operations, and associated activities would lead to some effects which are both adverse and unavoidable. These unavoidable adverse effects are categorized and examined in the following paragraphs.

A. Land Changes

1. Topography - The development of an oil-shale mining-processing-disposal complex at each of six locations would require roads, mining, and plant sites, waste-disposal areas, utility and pipeline corridors, and associated services during the productive life of a lease. These activities would change the existing pattern of land use and alter the existing topography.

   Estimates of the size of the areas affected at a given site, on the basis of 50,000 barrels per day production, were given in Chapter III for various methods of mining and waste disposal, and for operations involving shale oil upgrading and retorting. The estimates show that, except for open-pit mining, the total surface area of each lease for above-ground operations would probably be less than 2,000 acres over a 20-year period. For open-pit mining, from 5,000 to 7,000 acres would be required over the same period, depending on how the mine is developed.

   Waste disposal areas on flat land would create new "hills", which could be contoured and revegetated to restore scenic attractiveness. Canyon and gully disposal areas would gradually be converted into flatter areas, and also revegetated.

To some extent, these changes in topography would alter the appearance of the land and would affect natural vegetative cover until re-vegetation operations began. These changes would be adverse, in the sense that the area's present topography and semi-wilderness character would be altered. The degree to which these topographical changes are adverse, however, is a value judgment difficult to quantify. With proper restoration methods the scenic impact would be kept within limits acceptable to most people. Some enhancement might result, especially where areas are now deeply eroded, sparsely vegetated, and essentially unattractive.

2. Use Patterns - Where parts of the lease site areas are now used for livestock grazing,[1/] agriculture, or recreation, some unavoidable changes in use patterns would result.

The total impact would be slight for the region as a whole because the percentage of the region's total surface area affected by the prototype program would be small (about 0.5 percent). However, some local dislocations could unavoidably occur.

Leasing of public oil-shale lands would have little direct impact on agricultural activities in the oil shale region, since most agricultural lands are privately owned. There

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[1/] The impact on wildlife is considered in Section C of this Chapter.

would be some indirect effect, however, since some private agricultural lands may be located near present communities, and could be converted to business or residential use as a result of the increased urbanization which would be associated with the prototype leasing program. Any adverse effects on agricultural lands could be mitigated by proper community planning and zoning ordinances.

A greater population density would increase the recreational use of the region and decrease the present primitive aspects of many of these recreational forms. Increased vehicular traffic into off-highway areas could occur, unless regulated. Success ratios in hunting and fishing could decline. These impacts would be reduced by coordinated regulations by Federal and State agencies of the total recreational use of the region.

B. Water Resources Changes

1. Surface Water - Chapter III showed that a proposed prototype oil shale leasing program would require the diversion of water from the Colorado River and its tributaries, part of which would be returned. At the end of six years, at a production level of about 200,000 barrels of shale oil per day, the amount of diverted water could approximate 30,000 acre-feet annually for the region as a whole, of which 12,000 to 19,000 acre-feet would be consumed and 11,000 to 18,000 acre-feet returned to streams.

This water use would have an unavoidable impact on regional water supplies because any diversion and net consumption of existing water resources would deplete natural stream flow. For the prototype program, such disturbances would be modest. It is the goal of the proposed program to avoid any surface water degradation as a result of any activities conducted during operations. Unavoidable adverse effects on surface water quality might possibly arise later, but none are currently anticipated.

2. Underground Water - The disturbance of underground waters by mining operations, or by water used to return spent shale underground for disposal, could have an adverse effect on subsurface water quality. Because hydrologic knowledge of much of the region is inadequate, the extent of this impact cannot be predicted. Specific information developed during core drilling will reduce the risk of leasing areas where unavoidable adverse impacts on aquifers are likely to occur. Close monitoring of the quality of underground waters, and the prompt action required under the proposed program to change hazardous operations, would mitigate any adverse effects during operations.

C. Fish and Wildlife Changes

1. Localized Impacts - Construction and operation would have varying degrees of direct and indirect impacts upon fish and wildlife and their habitat in the immediate vicinity of the plants and along their appurtenant roads, surface facilities, and pipelines. The impacts would include such things as alteration of wildlife behavior and activity patterns; removal and reduction

of food and cover; and possible siltation during project development. Depending upon the characteristics of the specific lease site, species which would be most affected include mountain lion, bear, elk, mule deer, antelope, sage grouse, blue grouse, and migratory birds.

In the event of oil loss from pipelines or at handling facilities, the extent of impacts from such spills upon habitat and associated wildlife and fish populations would depend upon circumstances already summarized under probable impacts. The most significant effects would occur to any aquatic habitat and associated organisms within the area of spill influence.

Aquatic habitat is very small in the oil shale areas. However, were an oil shale operation established within the vicinity of such habitat, and if unpredicted or uncontrollable changes in the quality of local surface or ground water were to occur, there would most likely be impacts on fish and wildlife populations. Additionally, if use of ground water for development and operation caused a lowering of natural ground water discharges, such as springs and seeps, adverse impacts would occur upon associated ecological features, including wildlife and fish.

2. Ancillary Urbanization and Human Pressures - Certain species, such as mountain lion, bear, elk, and mule deer are by nature incapable of adjusting to the aggregate of human activities in a developing area (i.e. urban expansion; waste disposal; additional recreation

use; etc.). Although population declines for these species in the oil shale areas would not be expected to be dramatic, these and other intolerant species would be expected to decline over time as a result of oil shale prototype program population pressures. Added hunting and angling pressures indirectly resulting from the prototype program would be expected to reduce hunting and angling quality for some species and in local situations.

D. Other Changes

1. Air Quality - The operations conducted under the prototype program would not be expected to present any unique air pollution problems. Proper techniques already exist to adequately control emissions, including particulates, sulfur oxides, and nitrogen oxides potentially present in various flue gases, and the dusts produced in mining and shale disposal.

   It is not implied, however, that a requirement of zero air pollution could be imposed as a standard for the prototype program. Such a standard is not technically or economically feasible. However, it would be expected that all applicable Federal and State criteria on acceptable air quality standards could be met. Residual concentrations of sulfur and nitrogen oxides in flue gases after treatment, and from some solid particulates in gaseous discharges to the atmosphere would be minimal, but unavoidable for the program at the present state of technology. New control techniques now being developed for other industrial operations could be incorporated into this industry, which is at least 2 and, possible, 4 years from construction.

2. Urbanization - The increased urbanization of a region which is primarily rural, would be an unavoidable consequence of the prototype program. Since the benefits and costs of urbanized life versus rural life are a matter of personal value judgment, it is impossible to assess the degree to which the social environmental impact would be detrimental. To the degree that urbanization provides diversity of opportunity and choice; to the degree that the prototype program would result in minimal damage to the natural environment, the net social changes could be considered beneficial.

VI. Irreversible and Irretrievable Commitment of Resources

The purpose of this chapter is to examine those resources which would be consumed and those that would be altered irreversibly and irretrievably by the proposed prototype oil shale leasing program. Such commitments would include: the consumption of certain mineral resources; changes in the relief of the terrain and in land use patterns; and new directions in the patterns of community activities.

A. Consumption of Mineral Resources

The principal mineral resources consumed by the proposed prototype program would be the shale oil and associated products, and the water and other resources required in their production

Over the initial six-year period of the program, during which total production may be expected to rise gradually to 200,000 barrels per day, a cumulative total of approximately 220 million barrels of shale oil and shale oil products would be produced for consumption. To achieve such an output, 350 million tons of raw shale would have been processed, 50 million tons of useful products removed, and 300 million tons of processed spent shale discarded. In this same six-year period, about 40,000 to 60,000 acre-feet of water would have been consumed, and perhaps, some natural gas for plant fuel. Saline minerals may also have been removed.1/

1/ The quantities of natural gas and saline minerals have not been estimated, since these would be dependent upon the type of processing sequence employed.

After the initial six-year period, and for each 70 million barrels of oil produced (200,000 barrels per day), 110 million tons of raw shale would be processed, 16 million tons of useful products removed, and 12,000 to 19,000 acre-feet of water would be consumed each year.

B. Changes in the Land

The major environmental impacts of the proposed program upon the land were described in Chapter III. These include topographic changes at the prototype sites due to mining and surface disposal activities, and changes beneath the earth's surface as a consequence of underground mining. In addition, present land use patterns on about 0.5 percent of the total surface area would be irreversibly altered by mining and surface disposal, and by operations at plant sites, including both the plants and the associated utilities and service facilities. Increased urban requirements would also convert certain present rural areas of the region to residential and community use.

C. Changes in Fish and Wildlife Resources

Construction and continuing operation and habitation at and in the vicinities of the oil shale installations would entail localized and permanent reduction of habitat and disturbance of wildlife populations over the life of the projects.

Although the decreases would not be dramatic, increasing ancillary urbanization and human pressures resulting from the prototype program would cause a reduction in the wildlife habitat of less tolerant species across the oil shale area. Hunting and fishing pressures would increase with an unavoidable reduction of hunting and angling quality for some species and in local situations.

D. Changes in Socio-Economic Patterns

The increased economic growth resulting from the initiation of the prototype program would significantly alter existing social structures and institutions. The transition from a rural society to an industrialized one may produce intermediate community instability. Strains of rapid population influx could result in a dichotomy between the established and new inhabitants of the region. However, the intense industrialization of the affected areas, with consequent increased employment, greater capital flow, and broadening of the tax base would benefit the total social environment by upgrading existing community amenities, such as public schools, hospitals, libraries, water and sewage systems, etc. Existing pre-industrial life styles with their emphasis on recreational activities and subsistence economic patterns eventually would be exchanged for an urbanized way of life. In the long run, the societal impact could be a more broadly based stability of rural aesthetics intertwined with urban cultural amenities. The new tax income received by all segments of government (Federal, State, and local) would be a welcome addition to the economy at all levels. The net socio-economic environmental impact, therefore, could be of considerable benefit to the region.

VII. Short-term Uses of the Environment vs. Maintenance and Enhancement of Long-term Productivity

The prototype oil shale leasing program would inescapably involve commitment of a portion of the region's shale, land, water, and air resources. The extent of these commitments and an assessment of their environmental impacts have been previously detailed. However, the relationship between these proposed uses of the environment and the maintenance and enhancement of its long-term productivity must also be examined.

A. The Resource

By developing a portion of our oil shale resources, the Nation could acquire a new source of supply to help meet its growing needs. The development by the private sector of this important mineral resource would therefore appear to be in the national interest, insofar as future United States energy requirements are concerned. This would also be true of the potential utilization of the saline minerals associated with part of the publicly owned oil shales.

B. Water

Consumption by the prototype plants would constitute a net depletion of available regional water resources, but its use measured in terms of the utilization of a portion of the oil shale resources is a beneficial one. Given the controls envisioned for water use, degradation in regional surface water quality is not expected.

The effect of the program on underground waters is not as well defined because little is known about the aquifers of the region. As the prototype program develops, more data on the area's aquifers would be acquired which would be used to establish suitable monitoring procedures and controls to protect the underground water resource.

C. Air

Although all industrial activities affect air quality, the changes that may be caused by operations under this program could be kept within the acceptable limits now being established nationally by the Environmental Protection Agency for comparable types of industrial processing. Air quality, therefore, could be maintained at nearly its present level.

D. Land

Land uses would be changed from those of wildlife habitat and livestock grazing wherever surface operations are conducted. Possibly, where canyons and gullies would be used as disposal sites, there could be some enhancement in their appearance and usefulness as a result of contouring, fertilization, revegetation, and stabilization which would all be part of surface restoration operations.

E. Wildlife

The prototype program and associated urban development would result in certain localized and regional adverse impacts on fish and wildlife. As much as 0.5% of the oil shale area could be affected. Although some impacts would be unavoidable, many lend themselves to technological and regulatory control. The objective would be to maintain habitat with as little disturbance as possible. Therefore, the optimum relationship between program implementation and maintenance of long-term fish and wildlife productivity would involve cooperation among the government, industrial, and the private sectors in anticipation of adverse impacts, and implementation of continuing research, development, and control programs which would preclude, minimize, or mitigate the adverse impacts.

F. Economy and Community Life

Over the long-term, the economy of the oil shale region, the States involved, and the Nation could be enhanced by prototype development. The projected increases in employment, capital in-flow, personal income, and tax revenues that would occur have been quantitatively evaluated in Chapter III. These increases could provide incentives for greater upgrading of the private sector of the economy than has been projected.

An improvement of community facilities should be possible as a result of the expanded tax base. This, in turn, could act as an effective catalyst at State, county, and local levels for coordinated and comprehensive planning to ensure orderly growth as the prototype program develops. Both existing and new communities would benefit from better or new school systems, libraries, hospitals, parks, municipal water and sewage systems, streets, and airports.

Community life in the region would change. The rural character of the region would give way to increased urbanization, and employment in industrial occupations would take place. Recreational activities would increase with population growth and the increased demand should result in development of new recreational facilities.

It is difficult to make a value judgment on these social changes, and hence to determine whether a net enhancement in the lives of the area's residents would result from the prototype program. This is a question of personal assessment and opinion. But in an overall sense, the creation of more personal income for the Nation's expanding population would be regarded by most as a beneficial effect of the prototype program.

VIII. Alternatives to the Proposed Prototype Oil Shale Leasing Program

The principal alternatives to the proposed prototype leasing program are considered in this Chapter. Any option that leads to development, however, would probably have environmental impacts similar to those previously described in this Environmental Impact Statement.

A. Alternatives[1]

There are three broad alternatives to the proposed program. The first of these is development of public lands by the government; the second is for the government to take no steps to develop oil shale resources on public lands; the third is for the government to postpone development of the public oil shale lands at present, but to re-assess its position at regular intervals, with a view toward potential development at a future date. Each of these three alternatives is considered briefly below.

1. Government Development of Public Oil Shale Lands - There are a number of possible options for Federal development of the Nation's oil shale resources, including: (1) a government-financed demonstration plant; (2) a joint government-industry effort, in which costs are shared equally; (3) a government corporation, modeled upon COMSAT (the Communication Satellite Corporation); and (4) a government organization modeled after the TVA (Tennessee Valley Authority).

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[1] Alternatives to oil shale development have been examined in a number of publications. See for example: Oil Shale Advisory Board, Interim Report to the Secretary of the Interior, Washington, D.C., February 1965; Competitive Aspects of Oil Shale Development, Senate Hearings before the Subcommittee on Antitrust and Monopoly, 90th Congress, 1st Session, April and May, 1967; Federal Oil Shale Program, Senate Hearings before the Committee on Interior and Insular Affairs, United States Senate, 90th Congress, 1st Session, February and September 1967.

Precedent exists for each of the four options for government development, but none of the alternatives that involve extensive government participation are authorized by existing legislation as it pertains to oil shale. Both additional legislation and substantial amounts of money must be provided by Congress for any of these options to be viable. The environmental impact of any of these programs is expected to be essentially the same as that of the proposed prototype leasing program.

2. No Development of Public Oil Shale Lands - The government could determine to take no steps to develop oil shale resources on public lands. This would mean that there would be no direct environmental impact on public lands, but there might still be oil shale development on other lands. There are at least three oil shale tracts in private ownership which are sufficiently large to support operations, but their commercial potential cannot be assessed by the Department.

   If there is sufficient interest in oil shale, development on these private lands might be commenced. Generally speaking, conditions on these private lands are believed to be similar to those on the public lands in the oil shale area, and, therefore, the environmental impact would probably be similar. From such development, there might also be an indirect environmental impact on adjacent public lands. Development on private oil shale lands would proceed under environmental standards of Federal and State governments, but special environmental standards of the kind which it is proposed to tailor for each lease offered under the proposed prototype program would not necessarily be made applicable. Any successful oil shale development on private lands would probably lead to renewed demands for development on public lands, and, in that event, the dangers of a crash program discussed below might arise.

3. Delay Development on Public Lands - The government could delay the initiation of an oil shale program on public lands, and re-assess the situation from time to time to determine whether such a program should be started. This would avoid, on a short term basis, any effect on the environment, but in the long run the effect might prove more harmful. Potential environmental impact would probably be the same at a later date, but many of the things which must be learned to protect the environment cannot be learned except by actual experience. Delay or postponement of the proposed program may reduce the available time that is needed to resolve many technical and environmental uncertainties. Up to ten years would be required for that task under normal circumstances. Prolonged delay may leave no alternative but to react eventually with a crash program to develop this resource.

   By their nature, crash development programs frequently sacrifice environmental considerations and regional planning to technologic expediency. The balanced progress needed to resolve the complex interrelationship between the environment and technology is denied and orderly development is not possible.

APPENDIX A

THE OIL SHALE AREA: RESOURCES AND CHARACTERISTICS

I. Introduction

The 11 million acres of oil shale lands that lie in the three-State region of Colorado, Utah, and Wyoming are in a sparsely settled, semi-arid to arid region of moderately high elevation. Physiographically, the region ranges from the high, dissected plateau of the western slope of the Colorado Rockies, to the sparsely vegetated, arid plains in Wyoming. It is drained by Upper Basin tributaries of the Colorado River. Geologic uplift, stream erosion, and the varying degrees of resistance of rock layers to weathering control the land forms. Soil development ranges from essentially none to moderate.

The closest major cities are Denver, Colorado, and Salt Lake City, Utah, each more than 200 miles from the major oil shale areas in those States. The largest population centers within or adjacent to the oil shale areas are Grand Junction, Rifle, and Craig, Colorado; Vernal, Utah; and Rock Springs and Green River, Wyoming. The average population density of the whole oil shale area is approximately three people per square mile.

The major existing industries are oil and gas, limited uranium and vanadium operations in Colorado and Utah, and oil, natural gas, sodium (trona) and coal production in Wyoming. It is a predominantly rural area; agriculture, livestock raising, support and service activities, and recreation are the main nonindustrial pursuits.

The oil shale area provides an ecological combination of vegetative, climatic, physiographic, and cultural conditions, which provides an attractive habitat for big game species. The mule deer is regarded as the most important species. In addition to mule deer, the areas exhibit 6 additional species of big game, 3 species of small game, 27 species of migratory waterfowl and shorebirds, 6 species of upland game birds, 5 species of furbearers, 21 species of non-game mammals, 200 species of non-game birds, and 24 species of raptors (eagles, hawks, etc.). Several wild horse herds comprising about 500 animals range over the area. The wildlife resource contributes significantly to the economy and personal income of people living in the vicinity.

Fishery habitat is limited in the oil shale areas. Most of the available habitat supports non-game fish populations, although cutthroat, rainbow, and brown trout populations exist in limited headwater areas. Trout fishing in these headwater areas and isolated beaver dams is the major type of angling in the oil shale areas. Little systematic investigation of the Colorado River Basin fishes has taken place since 1900, and the status of many species is not known. Existing information indicates that the basin has retained a large number of native species, and several of these may soon be classified as rare or endangered.

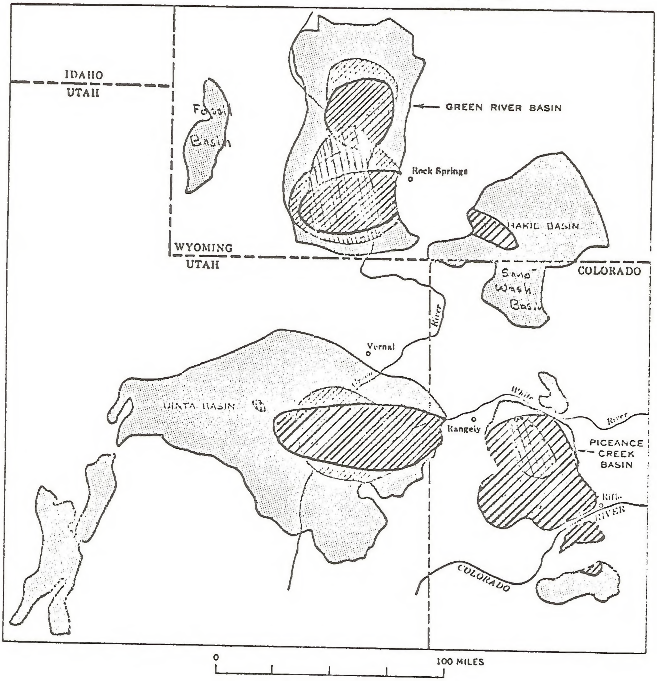
II. Mineral Resources

A. Oil Shale - The Green River Formation in the three-state region (see Fig. A-1) contains known oil shale deposits with about 600 billion barrels of equivalent oil in the higher-grade deposits (averaging more than 25 gallons per ton and a minimum of 10 ft. in thickness). Recovery of even a fraction of this resource can significantly supplement our growing consumption of oil which now totals slighly over 5 billion barrels each year. In lower grade deposits (averaging 15 to 25 gallons per ton) there are an additional 1,200 billion barrels. Some 80% of the known higher grade reserves are located in Colorado, 15% in Utah, and 5% in Wyoming.

Colorado has the smallest geographical area of oil shale, but the richest, thickest, and best known deposits. In the Piceance Creek Basin the higher grade deposits (as previously defined) total some 480 billion barrels, in strata varying from 10 to 2,000 ft. in thickness, and with overburdens from zero to 1,600 ft. Substantial quantities of saline minerals are also present in the northern half of the Basin.

The largest oil shale-bearing area of the Green River Formation occurs in Utah. The richest shales occur in the east-central part of the Uinta Basin, at depths up to several thousand feet below the surface, and in thicknesses up to 700 ft. These rich deposits are equivalent to a total of as much as 90 billion barrels of oil.

Figure A-1 - Oil-shale Areas in Colorado, Wyoming, and Utah



EXPLANATION

░ Area of oil shale deposits	▨ Area of 25 gallons per ton or richer oil shale 10 ft. or more thick	▥ Area of nahcolite or trona deposits

(Being redrafted)

Total known deposits of rich shales in Wyoming located in the Green River Basin are estimated to be 30 billion barrels equivalent, the smallest of the rich deposits in the three states. Leaner shales exist over a wider area, including the Washakie Basin. The higher-grade shales are frequently associated with the sodium mineral, trona. Overburden ranges from 400 to 3,500 ft.

B. Saline Minerals - Sodium minerals have been discovered in association with certain deep shales of the Green River Formation, principally in the Piceance Creek Basin of northwestern Colorado. Trona (67 billion tons) and halite (salt) are associated with or adjacent to the shallow oil shale in the Green River Basin in Wyoming, however, the existence and/or extent of dawsonite, a sodium aluminum mineral, and other saline deposits has not been established. In the Uinta Basin of Utah, the existence of sodium minerals has been shown in a few core holes, but again, the extent of the deposits has not been defined.

In Colorado's Piceance Creek Basin, dawsonite, nahcolite, and halite are intermixed or intermingled with oil shale in certain zones underlying the area. Three nahcolite strata are present near the base of the saline zone (Fig. A-2), and two halite-bearing strata exist in the upper part of the zone. The dawsonite deposits are finely commingled with the oil shale (and other saline minerals), in beds which are up to 700 ft. thick near the center of the Basin. The dawsonite (a dihydroxy sodium aluminum carbonate) is technically suitable for recovery of alumina by roasting and leaching.

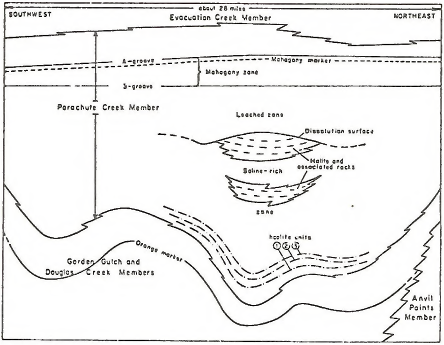


Figure A-2 —Diagrammatic southwest-northeast stratigraphic cross section through the approximate depocenter of the Piceance Creek basin, Colorado. This figure shows the relationship of the saline-rich zone to the enclosing rocks of the Green River Formation.

C. Other Minerals - Within that portion of the Upper Colorado Region in Colorado, Utah, and Wyoming containing the Green River Formation oil shale, there are several other mineral deposits of significance. Among the more important of these are petroleum, natural gas, bituminous rocks, tar sands, and coal.

The total potential crude oil reserves of the oil shale regions are approximately 680 million barrels. An additional 5 billion barrels are inferred to be present. Total natural gas resources are estimated to be of the order of 85 trillion cubic feet. An additional 300 trillion cubic feet may exist in tight formations, but are not presently economically recoverable. However, the development of suitable techniques may permit recovery in the future. Certain of these oil and gas fields lie in close proximity to the oil shale deposits.

Gilsonite deposits, a solid bitumen occurring in veins, occur primarily in Uintah and Duchesne Counties, Utah in proximity to the oil shale area. The total resource is estimated to be some 36-40 million tons capable of yielding approximately 75 million barrels of petroleum with the balance converted to coke.

Bitumens in other rock asphalts occur in Carbon and Uintah Counties (Utah), to the extent of over 4 billion equivalent barrels of oil.

Coal beds of present or future commercial value (15 to 30 inch minimum thickness) are adjacent to many of the oil shale deposits.

Beds of lesser thickness, or beds probably buried too deeply for commercial exploitation are even more extensive, and underlie much of the oil shale. The "indicated" coal reserves alone, in or adjacent to the oil shale regions of the three states, may be of the order of 6000-8000 million tons, of which two-thirds are in Wyoming and most of the remainder in Colorado.

III. Piceance Basin Area, Colorado

A. The Physical Setting - The term "Piceance Creek Basin" is sometimes used to describe a major geologic, structural, and sedimentary basin in Rio Blanco, Garfield and Mesa Counties, Colorado. The portion of the Basin containing the principal oil shale deposits is a dissected plateau, known as the Roan Plateau, bounded by steep escarpments which face the Colorado River on the south, the White River on the north, the valleys of Government and Sheep Creeks on the east, and Douglas Creek on the west.

Piceance Creek, Yellow Creek, and tributaries of Douglas and Sheep Creeks drain the northern part of the oil shale area and are tributaries to the White River. Parachute Creek and Roan Creek drain the southern part of the oil shale area, into the Colorado River. Most of the Federal oil shale lands are located in the drainage basins of Piceance Creek and Yellow Creek. Smaller deposits, in Battlement and Grand Mesas south of the Colorado River, are excluded from consideration here.

This area is located on the "western slope" of Colorado, at some distance from any major population center. Access routes include U.S. Highway 6 along the Colorado River, Colorado Highway 64 along the White River, and Colorado Highways 13 on the east and 139 on the west. Many unsurfaced roads and rough trails lead into and across the area from the main access routes. A paved county road traverses the area along Piceance Creek.

The topography of the shale-bearing area is somewhat unique. The differential resistance to erosion has produced ridges and valleys with local relief of 200 to 600 ft. generally oriented north and north-easterly in a nearly parallel pattern, as illustrated in the aerial view, Fig. A-3.

Elevation varies from about 5,250 feet along the White River to a maximum of about 8,700 feet for some ridge crests on the south.

The Piceance Creek area is sparsely settled, with a population of 150 people in the Basin itself. The inhabitants are generally widely dispersed and are engaged in the livestock, mineral, oil and gas industries, or in farming.

B. Land Status - Total land area in the two Bureau of Land Management (BLM) planning units of major significance is 805,420 acres. Land ownership in the two units is as follows:

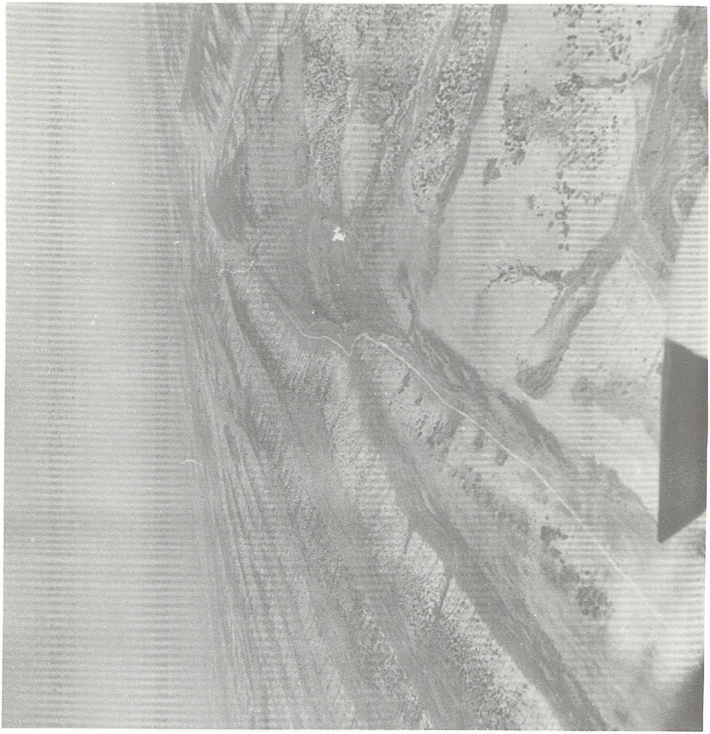


Fig. A-3. Aerial view Colorado Oil Shale Country in central part of Piceance Basin.

BLM Planning Unit	% Federal	Public Land Acres	State Acres	Private Acres
Piceance Basin	61%	264,580	11,526	97,780
Yellow Creek	79%	343,989	18,823	68,719

C. Climate - Annual precipitation in the Piceance Basin varies from approximately 12 inches in the extreme northwest corner to approximately 24 inches in the southwest corner. The area is generally classified as semi-arid.

Slightly less than half of the precipitation occurs as snow during the months of December to April. Spring precipitation is usually very light. During the latter part of the summer occasional thunderstorms with accompanying flash floods, ranging from light to very severe, occur throughout the area. Fall weather varies from fair days to infrequent rain or snow storms.

The area is subject to thermal extremes, with summer temperatures reaching 100 degrees F and winter temperature dropping to 40 degrees below zero.

The frost free season varies from 124 days at the lowest elevations to 50 days at upper elevations. The dry climate and relatively short growing season permit restricted growth of small quantities of native irrigated hay, corn for silage, and some small grains along Piceance Creek, Yellow Creek, and the White River.

Climate thus has a limiting effect on agriculture and ranching in the area. The upper elevations are grazed during the summer by cattle and deer. The lower elevations are used by cattle, deer, and sheep as winter range.

D. Nonmineral Resources -

1. Vegetative Resources - Vegetation in this area is predominately of three major types: sagebush, mountain shrub, and pinon-juniper. Other vegetation in lesser quantities includes greasewood, saltbrush,conifers, broadleaf trees, and grass. Limited cultivated valley lands (5%) produce mostly hay crops.

   The sagebush and mountain shrub types cover about 60% of the area. Big sagebrush is conspicuous on the divides, in valley flats, and in open areas, sometimes along with pinon-juniper. The mountain shrub type may include oakbrush, serviceberry, or mountain mahogany, with an understory of grass. The pinon-juniper type covers about 36% of the area.

2. Timber - There is no commercially valuable timber within the prospective area of development. The juniper is cut for posts and poles by local ranchers.
3. Fish and Wildlife - For many years this basin's wildlife reresources has been an important recreational source of both national and local significance, providing benefits for local ranchers, businessmen, hunters, and the general economy of surrounding communities. The Colorado Game, Fish and Parks Division has active programs in managing, preserving, and

maintaining the basin's wildlife resource. The agency has acquired surface fee title ownership to over 26,000 acres and cooperative resource management control over approximately 150,000 acres of habitat. It has also conducted a continuing and systematic series of game investigations and has promoted the development of a road system for public hunting access.

a. Big Game - The 805,000-acre basin constitutes Colorado's most important mule deer range. It is the principal wintering ground for the migratory White River herd, and every square mile is utilized as summer range. The 605,000-acre Game Management Unit 22 had an annual average harvest of 6000 deer during the period 1960-69. Hunting pressure has average 5,611 hunters. The hunting significance of the Piceance Creek Basin lies in the fact that approximately 1% of Colorado lying within the basin has been responsible for around 10% of the State deer harvest. Deer hunting alone has provided an average of 39,600 recreational days use annually for the period 1960-69.

Though not abundant, black bears exist throughout the area. A few are taken each year by hunters.

In 1968 the Colorado Game, Fish and Parks Divisions introduced a small herd of bison in the Piceance Creek area. This species was given full protection by the 1970 Colorado Legislature.

A herd of 100-200 elk inhabit the area, using it more in winter than in summer.

Mountain lions are regarded as scarce, and it is estimated that possibly 15 of these animals live within the Piceance Creek Basin. Abundance and location of this species have been shown to coincide with deer numbers and movements.

A herd of approximately 50 wild horses exists in the basin. They have no legal status as wildlife nor are they protected but may be considered to have aesthetic value.

b. Small Game - Small mammal species are widely distributed, and possible densities of cottontail and snowshoe hare are 150-200/sq. mile and 125/sq. mile, respectively.

c. Small Game Birds - Sage grouse, blue grouse, and ring-necked pheasants are present in small, isolated populations. Sage grouse are the most abundant, approaching a fall density of 10 birds/sq. mile in acceptable habitat.

d. Migratory Game Birds - A population of approximately 1000 waterfowl uses the waters of the area--more in summer for breeding than in winter. Mourning doves breed over the area, and band-tailed pigeons are seen occasionally.

e. Fish - Although statistics on angling pressure and success are not available, a limited number of headwater trout fishing area provide a small sport fishery. Since vehicular access to these streams is seldom closer than 1/2 mile, semi-wilderness conditions exist.

Upper tributaries of oil shale area streams are isolated by high falls, and these may contain relict populations of the Colorado River cutthroat, a species which may soon be recognized as rare or endangered.

4. Land Use - Public Lands in the Piceance Creek Basin serve primarily as forage areas, wildlife habitat, limited natural gas and natural gas liquids production, as a watershed, and for outdoor recreation. These uses have not changed appreciably in recent years. The public domain lands are all included in two Grazing Districts administered under the Taylor Grazing Act. About 60,000 authorized animal unit months of forage use are distributed among 45 permittees.

5. Watersheds - During years when precipitation is average or better, live water can be found in all the major drainages in the Basin. Flowing springs that provide high quality water are located at higher elevations, at the head of the drainages. The discharge of a number of springs at lower elevations contribute large quantities of soluble salts, and wells produce water of varying quality.

   Stream and channel characteristics vary from the higher elevations to the lower elevations. At the higher elevations V-shaped valleys predominate. As the elevation changes downstream the main valleys widen and contain thick alluvial deposits that are essentially coalesced alluvial fans. In some cases vertical walls are present which range from 20 to several hundred feet high.

Stream erosion is chiefly confined to upland and upper stream valleys. Some lateral stream erosion has cut cliffs in the lower valley walls. Trails and roads along steep upper slopes have had a striking effect in concentrating runoff water. Deep gullying and bank cutting are visible along all intermittent creeks, and head cutting is common on side drainages. Summer storms occasionally wash out bridges and gulch crossings within the area, leaving detrimental flood deposits on alluvial fans and bottomlands.

Typical erosion conditions found on the two BLM planning units (Piceance and Yellow Creek), by acreage of public land are:

Erosion Classification (Percent)

	Slight	Moderate	Critical
Piceance Unit (264,00 acres)	12%	85%	3%
Yellow Creek Unit (344,000 acres)	3%	67%	30%

IV. Uinta Basin, Utah

A. The Physical Setting - The Uinta Basin, a broad structural and physiographic basin, is a depression bounded on the east by the cliffs west of the Douglas Creek Arch, the Uintah Mountains on the north, the Wasatch Mountains on the west, and the Roan Cliffs on the south. The richest and thickest deposits of oil shale lie mostly in the Uintah County portion of the basin, which is thus the area of primary concern.

Access to this area is gained, from the north, by U. S. Highway 40; and from the south, by U. S. Highway 6 and 50. Gravel surfaced State and county roads cross the basin in a general north-south direction. Jeep trails, and seismic and oil exploration roads crisscross the basin in a random manner. Population within the three principal BLM planning units is approximately 470.

The Green River is the main flowing body of water in the area cutting through the best oil shale deposits in a northeast to southwest direction. The other source of water is the westward-flowing White River, which empties into the Green within the bounds of the Uinta-Ouray Indian Reservation. The Duchesne and Uinta River enter the Green River from the west.

The topography consists of rough mountain terrain and flat valleys, sharply dissected by deep gulleys with adjoining rock capped ridges. Oil shale crops out in cliffs and ledges on the south and east sides of the Basin. Elevations vary from 4,600 to more than 8,000 feet. An aerial view of a typical oil shale exposure is shown in Fig. A-4. The area drains into the White and Green River systems and eventually into the Colorado River.

B. Land Status - The total land area in the three principal BLM planning units involved is 1,091,959 acres. Land ownership in the three units is:

BLM Planning Unit	% Federal	Public Land Acres	State Acres	Private Acres
Bonanza	82.5%	337,518	46,295	19,278
Rainbow	77%	299,424	52,259	37,874
Book Cliff	82%	239,971	36,652	17,112

C. Climate - This area is semi-arid, characterized by low relative humidity and a wide range of daily temperatures. Summer

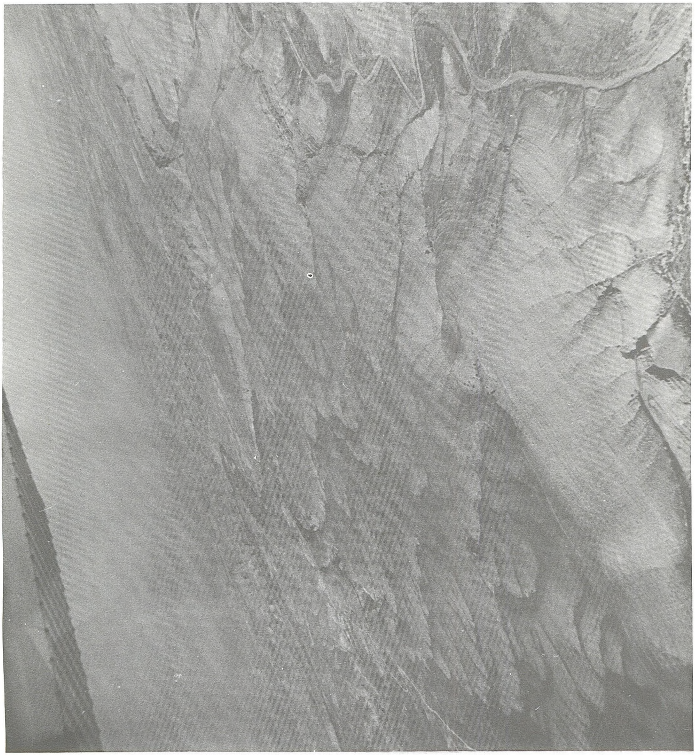


Fig. A-4. Aerial view of Green River Formation escarpment in west wall of Hells Hole Canyon, Utah.

daytime temperatures reach the 80's and 90's, while nights drop to the low 50's. Winters are cold, with day temperatures ranging from -20 degrees F. to 28 degrees F. during January. Mean annual temperature is 45 degrees F.

Growing seasons vary greatly, with records showing frost-free periods of 90 days to 218 days annually. The average growing season is about four months, from late May to late September.

Precipitation averages about 7 inches at the lower elevations and 15 inches at the higher levels. Records show that about 55% of the percipitation falls as rain during the growing season and the remaining 45% falls as winter snow. Most rainfall comes from thunderstorms, which are short-lived, but of high intensity. As a result, most of the moisture is lost through rapid runoff and evaporation. Snowfall is light, averaging 30" annually. However, snow melt in the spring is slow, allowing the soil to absorb most of the snow moisture.

Winds are irregular and light, except when associated with local thunderstorms. Although there is little wind erosion, winds affect the vegetation of the area by evaporating moisture from the soils before it becomes available for plant use.

D. Nonmineral Resources

1. Vegetative Resources - This area has five major vegetative types, distributed as follows: pinon-juniper - 10%; sagebrush-grass-10%; desert shrub - 60%; salt desert shrub - 15%; and mountain browse - 5%.

2. Timber - There is no commercially valuable timber within the prospective area of development. Some juniper trees are cut for posts and poles.

3. Fish and Wildlife

   a. Big Game - Utah's best oil shale area provides 1,335,000 acres of important mule deer winter range, of which 250,000 acres are considered critical as winter feeding areas. An average annual harvest of 8000 mule deer has been recorded in this area.

      Bears have been reported in the area but are scarce.

      Transplanted antelope have become established and are increasing in numbers. Additional transplants into the area are planned by the Utah Fish and Game Division.

      Small numbers of elk are present in restricted areas.

      Mountain lions exist in the area, but no data exists to reflect the population status.

      Bureau of Land Management estimates indicate that a herd of about 130 wild horses inhabit the Utah oil shale lands.

   b. Small Game - The cottontail is the most important species with an annual harvest varying from 10,000 to 15,000.

   c. Small Game Birds - Sage grouse occur in limited numbers with restricted distribution. The Chukar partridge has been introduced to the area and the population is increasing. Over 1000 Chukars are harvested annually, and more transplants are anticipated.

d. Migratory Game Birds - Use of oil shale area by waterfowl is limited to migration and breeding, mainly along the peripheral Green River. Private ownership and low access availability restricts hunting.

e. Furbearers - Muskrat, beaver, and mink population exist along the Green River.

f. Fish - Headwater areas provide some trout fishing, although heavy siltation and poor water quality has created a generally degraded fish environment. Three rare fish species, the Squawfish, Humpback Sucker, and Bluehead Sucker, inhabit the Green River on the periphery of the oil shale area.

4. Land Use - The generally semiarid and severe climatic nature of the area limit any cultivation of new lands for crop production. Most of the lands having agricultural potential are along the stream valleys and are already in private ownership. Vernal is the nearest population and community center. Any expansion of population and accompanying development is expected to take place in Vernal or other established communities.

5. Watersheds - The watersheds in this area are highly erodible and contribute a high silt load to the Colorado River system. Soil erosion conditions on the three units (Bonanza, Rainbow, and Book Cliffs) containing 875,000 acres of public lands are:

Erosion Classifications

	Slight	Moderate	Critical	Severe
Bonanza (337,000 acres)	---	9%	64%	27%
Rainbow (299,000 acres)	1%	45%	54%	---
Book Cliffs (240,000 acres)	15%	77%	8%	---

V. Green River Basin, Wyoming

A. The Physical Setting

The Wyoming oil shale deposit areas are bounded on the west by the Wasatch Mountains; on the north by the Wind River Range, the Green Mountains and Seminoe Mountains; on the east by the Medicine Bow Range; and on the south by the Uinta Mountains. This area of southwestern Wyoming includes all of Sweetwater, and part of Lincoln, Sublette, and Carbon Counties. The area of principal concern, however, is that portion of Sweetwater County which contains the richest and thickest deposits of oil shale. The best oil shale lies within the Green River structural basin. Good quality oil shale also underlies the western part of the Washakie Basin.

The best deposit of oil shale (Green River Basin) is cut west to east by Interstate Highway 80 and north to south by U.S. Highway 187. Jeep trails and mineral exploration roads in the area are numerous.

The Green River is the principal flowing water source in the immediate area, with the Big Sandy furnishing the only other source of live water. Drainage of the area flows into these two streams.

Topography is structurally controlled, varying from synclinal valleys to monoclinal slopes, with hills and ridges having a steep face on one side and a gently sloping face on the other side. This is illustrated in Fig. A-5; an aerial view of the Kinney Rim area. Elevations range from about 5,000 to 8,000 feet. Badlands are common in some of the soft mudstone of the area's Bridger Formation.

The area is generally underlain by soft shales and fine grained sandstone of Cretaceous and Tertiary age. Weathering of these beds and stream transport of material have filled the valleys along major streams with alluvium. There has been only slight soil development.

The population of Sweetwater County which encompases the major Wyoming oil shale areas is 18,301 with approximately 15,800 concentrated in the towns of Rock Springs and Green River.

B. Land Status

County	% Federal	Public Land (Grazing Dist.) Acres	Reserved Public Lands	State Acres (Approx.)	Private Acres (Approx.)
Sweetwater	69%	2,130,328	2,244,302	140,200	1,687,000

C. Climate

Annual precipitation in the Wyoming oil shale area varies from approximately 7 to 21 inches, considerably less than surrounding highlands; consequently the area is considered semiarid.

Seasonal distribution of precipitation is variable, but the annual total precipitation changes little from year to year. Winters are cold, summers short and hot. Most of the precipitation

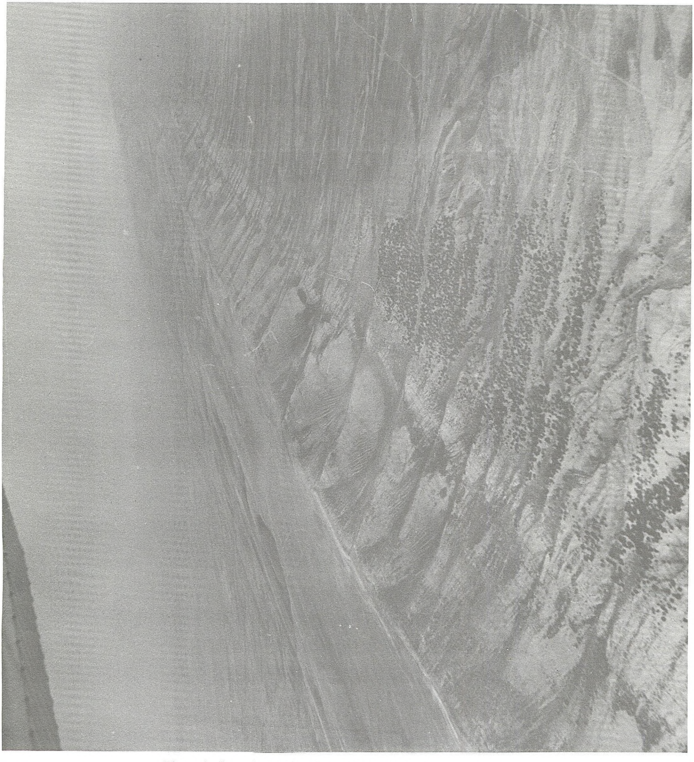


Fig. A-5. Aerial view of oil shale exposure in Kinney Rim Wyoming comes as winter snow. The relatively dry summers have occasional thunderstorm with rapid runoff.

The temperature range in the area is extreme. Summer temperatures may reach 90 degrees F. and winter temperatures can drop to -40 degrees F. July is usually the hottest month and January the coldest. Temperatures within the area vary considerably.

The frost-free season varies from 50 days to 120 days. The dry climate and limited growing season permit only the growth of alfalfa hay, native hay, and some small grains along some of the major drainages, and at the Eden Reclamation Project.

The area is grazed by livestock for most of the year. Cattle graze the area primarily in the spring, summer, and fall, and sheep primarily in the fall, winter, and spring. Antelope and deer also use the area throughout the year.

D. Nonmineral Resources

1. Vegetative Resources

Vegetation consists of grass and desert shrubs, including belts of mesophytic shrubs. There are three distinct vegetative types, of which the sagebrush-steppe (Artemesia-Agropyron) is the major. Juniper - pinon woodland if found on the higher knolls, hills, and north slopes, and saltbush-greasewood in the flats of some of the drainage basins.

The vegetation retards soil erosion, serves as livestock and big game forage, and provides food and cover for small game species.

2. Timber

There is no commercially valuable timber within the prospective area of development.

3. Fish and Wildlife

The Wyoming Basin oil shale lands possess significant fish and wildlife values. The Wyoming Game and Fish Department has plans to acquire the Red Creek Basin Tract south of Rock Springs for mule deer, elk, and antelope management purposes, and the Chilton Ranch Tract north of Rock Springs as an elk and deer management area.

a. Big Game - High quality browse and trees provide food and cover for mule deer in much of the proposed oil shale area. An annual average harvest of approximately 5000 mule deer are taken by about 8000 hunters.

Despite a low population of black bears, in 1969 an estimated 900 man-days were spent by 140 persons hunting this species.

The Wyoming Basin is one of the State's most important antelop habitat and harvest areas, supporting a higher density population. Approximately 1,500 hunters use this area annually, and hunter success is better than 90%.

Several small herds of elk exist in the oil shale areas including: one in the sand dune area east of Eden; one in the Pilot Butte area; and one in the southern portion of the Pine and Little Mountain area. These animals range over portions of the tri-state area, and hunting seasons are provided in all three states. There are important elk range areas north, west, and south of Kemmerer, Wyoming. Annually, about 1,400 hunters spend over 6000 recreational man-days hunting elk in Wyoming.

A limited herd of Shira moose occupy the riparian oil shale lands along the Green River and its tributaries. In 1969, 36 hunters harvested 32 animals.

Mountain lions occur in a rather even density over the Wyoming oil shale lands. No data are available on the existing number of this species.

It is estimated that about 300 wild horses inhabit the Wyoming oil shale lands.

b. Small Game - No reliable data are available on distribution or densities. However, the cottontail, coyote, and fox are regarded as common.

c. Small Game Birds - The Wyoming Basin is an important sage grouse area with the Eden Farson area exhibiting one of the highest densities of this species known to exist. In 1969, 7,776 hunters spent 17,843 recreational man-days harvesting 39,876 sage grouse. Ruffed grouse, blue grouse, and chukar are sought by around 300 hunters annually, and the harvest for each of these species varies from 200-700 birds per year.

d. Migratory Game Birds - In 1969, it is estimated that about 8000 ducks and 795 geese were bagged in the limited available habitat along the Green River.

e. Fish - The Flaming Gorge Reservoir and the Green River are the major sport fisheries areas in the oil shale lands. Flaming Gorge Reservoir is considered to provide excellent angling, and in 1970 it was reported to provide 232,000 anglers with 367,000 fish. The Green River provides a fair to good trout fishery. The section from Big Island to Fontonelle Reservoir provided an estimated 4,700 trout in 1970, while the section from Big Island to the Kincaid Ranch provided an additional 3,525.

The Bear, Hams Fork, and Little Snake Rivers are considered to vary from fair to poor in angling quality. The Little Snake River from Baggs to Savory is fair with good potential for improvement. The upper reaches of the Little Snake River have been dedicated to the preservation of the Colorado River cutthroat trout.

Although little data are available on the sport fishery resource in the smaller streams, some of the more significant trout habitat exists in headwater streams in the oil shale area.

4. Land Use

Public lands in the Wyoming shale basins serve primarily for forage and mineral production, and as wildlife habitat, as well as for recreation, and as a watershed. The only use that has changed appreciably in recent years is recreation, which has increased with development of the Flaming Gorge National Recreation Area. The public domain lands are in two grazing districts administered under the Taylor Grazing Act.

Ranchers are authorized to graze several thousand sheep and cattle in the area, and mineral activities are being conducted.

5. Watersheds

During years when precipitation is normal, live water can be found in most of the major drainages in the basin. There are flowing springs that provide good quality water at several of the higher elevations at the heads of major drainages. Also, several water wells have been located as a result of oil and gas exploration, and some wells have been drilled for livestock water.

The oil shale area comprises an important segment of the watershed of the Green River. The land is highly erosive and now yields heavy silt loads to the Green River drainage and ultimately to the Flaming Gorge Reservoir. Erosion is chiefly confined to upland divides and stream valleys. Stream and channel characteristics vary with elevation. At lower elevations the stream bottoms are wider and more deeply cut. Head cutting and active lateral erosion, with some vertical wall formation, are frequent. Trails and roads have had a strong influence in concentrating runoff. Bridges and creek crossings are occasionally washed out by spring runoff and summer storms.

VII. Summary

The characteristics of the three state segments of the oil shale area are markedly similar in many respects, in addition to the presence of oil shale. Climate, land uses, population and major resources are much the same in each state. The principal differences lie probably in landforms and the physical characterisitcs (extent, exposure and richness) of the known oil shale resources.

The oil shale resource and its associated saline minerals are the major known undeveloped mineral resources in the region. However, it and all other components of the resource systems are interrelated and cannot be considered separately. The region is also a major segment of the Upper Colorado River Drainage with attendant water and watershed considerations.

APPENDIX B

OIL SHALE PROCESSING

I. Surface Processing

Oil shale processing on the surface would require the handling of large amounts of materials. Figure B-1 indicates the materials flow through such an operation beginning with mining and ending with shale oil products and, possibly, associated minerals.

The amount of oil shale needed to support oil shale production rates up to one million barrels per day, and the volume of both the shale in place and after mining and retorting is detailed in table B-1. Because the volume is greater following processing, not all of the material can be returned to the mine, if this disposal method is chosen.

The major processing steps needed to convert oil shale into shale oil are outlined below. For specific information concerning any of these steps, see the publications referenced in Appendix C.

A. Mining

Oil shale mining can be conducted either at the surface or underground. The former, usually described as open-pit mining, involves removal and disposal of the surface material before the oil shale can be mined. The quantity of overburden material significantly affects the development time and economics. Current open-pit techniques and existing large-scale equipment are expected to enable mine development at relatively low costs, although disposal - restoration costs will be greater than similar costs for underground operations.

Figure B-1. - Oil Shale Surface Processing Systems

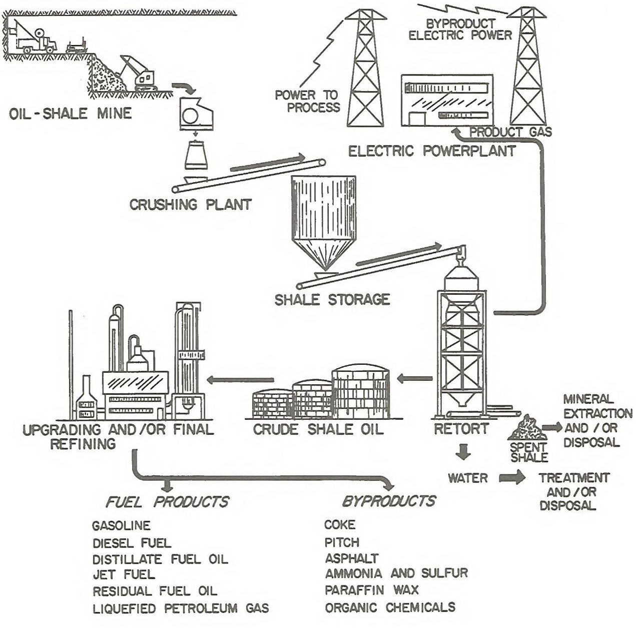


Table B-1 - Volume of shale in place and after mining and retorting for various shale-oil production rates.

Shale oil production, barrels per day	Shale mined, million ton per year	Volume of shale, billion cu. ft. per year 1/	
		In place	After mining and retorting
50,000	27	0.4	0.6 - 0.7
150,000	82	1.2	1.7 - 2.1
550,000	301	4.5	6.0 - 7.5
1,000,000	550	8.2	11.0 - 13.7

1/ Dependent upon size of material discharged from retorting system.

The room-and-pillar method has been extensively tested for underground mining of oil shale. In this development plan a maximum of about 75 percent of the shale can be removed. The remainder is left as pillars to prevent surface subsidence. It is expected, however, that some mining, particularly deep mining operations, would provide substantially lower total extraction percentages. Room-and-pillar mining is characterized by large rooms over 60 feet in height, separated by the support pillars. Entry to the oil shale to be mined can be gained either from the surface, by vertical shaft, or from the face of an oil shale outcrop.

B. Crushing and Conveying

Regarded as necessary parts of any integrated processing system, crushing and conveying systems are technically well-established, and reasonable in cost. The selection of specific equipment is primarily based on the size of the oil shale fragments needed for subsequent processing.

C. Retorting

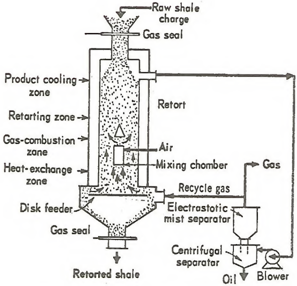
Literally thousands of retorting processes have been patented worldwide for the production of oil from oil shale. Three processes that have been tested using large experimental equipment appear at this time to offer reasonable possibilities of technical and economic success if scaled up to commercial design size. These retorting methods include the Gas-Combustion process developed by the Bureau of Mines, the Oil Shale Corporation (TOSCO) process, and the Union Oil Company process. In each system, heat is applied to raise the temperature of the oil shale to about 900 degrees F., where the solid organic material (kerogen) is converted to a liquid. The equipment, method of heat application, and operating procedures differ markedly for each system, as indicated in figure B-2.

D. Product Upgrading

Oils from the retorting processes, with the possible exception of the TOSCO process, will require upgrading before the oil can be transported through pipelines to the final product refineries, which are expected to be located outside of the oil shale region. Modern refinery processes are suitable for subsequent upgrading. Each of the three retorts also produce a retort gas that may be used within the plant as a fuel, or alternatively, to generate supplemental electrical power for nearby communities.

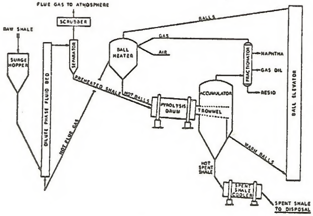
Spent shale may be in the form of solid particles ranging from 3 inches in diameter to a fine powder, depending on the retorting

Figure B-2. - Distinguishing Features of Three Possible Commercial Retorting Systems



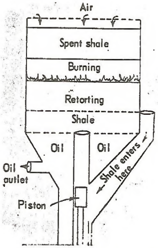
GAS - COMBUSTION RETORT

Recycle gas is mixed with air and burned within the retort. Gases flow upward and shale moves downward.



TOSCO RETORT

Ceramic balls transfer heat to the shale. No combustion takes place in retort.



UNION OIL RETORT

Shale is introduced near bottom of retort and forced upward. Air enters at the top and flows downward.

method used. It will normally be dry, but it may be wet if it is processed to recover saline minerals. Disposal will therefore depend on the physical characteristics of the material, its water content, and the location of the disposal area, whether surface or subsurface. If it is to be returned to the mine, this will affect the mine development plans.

E. Saline Minerals

Various processes for recovery of the saline minerals associated with the oil shales have been proposed. In one of these the intermingled dawsonite and oil shale are first retorted at 900 degrees F to recover shale oil. (If nahcolite is also present, it might be partially separated prior to retorting, by fine grinding and screening, because it tends to concentrate in the fines).

The spent shale is next roasted at 1200 degrees F. to remove residual carbon and produce sodium aluminate. The soluble sodium aluminate is extracted with 4% soda ash solution, carbonated to aluminum hydroxide, precipitated, and calcined to alumina. The spent shale is then sent to disposal.

The economical recovery of alumina, soda ash, and nahcolite (potentially valuable for removal of sulphur oxides from stack gases) from the deep oil shales has not yet been demonstrated on a large scale, nor have the effects of their recovery been tested by current markets for these chemicals.

F. Summary

The mining of oil shale, its surface retorting and processing, involves a number of material handling steps for which adequate information already exists to estimate the environmental effects associated with development. These effects and the safeguards required to achieve the desired environmental objectives of the proposed prototype oil shale leasing program are outlined in other sections of this Environmental Impact Statement.

II. In Situ Processing System

In situ oil shale operations contemplate removal of the oil from the shale by heating the shale while it is underground. A design concept is described in the Wyoming State report[1/] and is reproduced herein as figure B-3. Various means of supplying or creating the heat have been proposed, with several methods having been tested in field experiments. However, a commercial technique has yet to be demonstrated. Presently proposed heat sources include underground combustion, hot natural gas, hot carbon dioxide, superheated steam, hot solvents, and combinations of two or more of these. It is anticipated that paths for introducing heat underground could be provided through wells, mine shafts, and tunnels, fractures created by a variety of techniques, or by a combination of these.

Surface operations are relatively small in scope for in situ recovery, and the problems associated with mining and spent shale disposal are absent. Because of this, disturbance of the original land surface and vegetation is expected to be minimal. Earth moving will be limited mostly to grading for well locations, a plant site, and field roads. It is anticipated that less than ten percent of the land surface over an in situ recovery project will be affected

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[1/] Wyoming Oil Shale Environmental Planning Committee, Environmental and Economic Report on Wyoming Oil Shale. State of Wyoming, February, 1971.

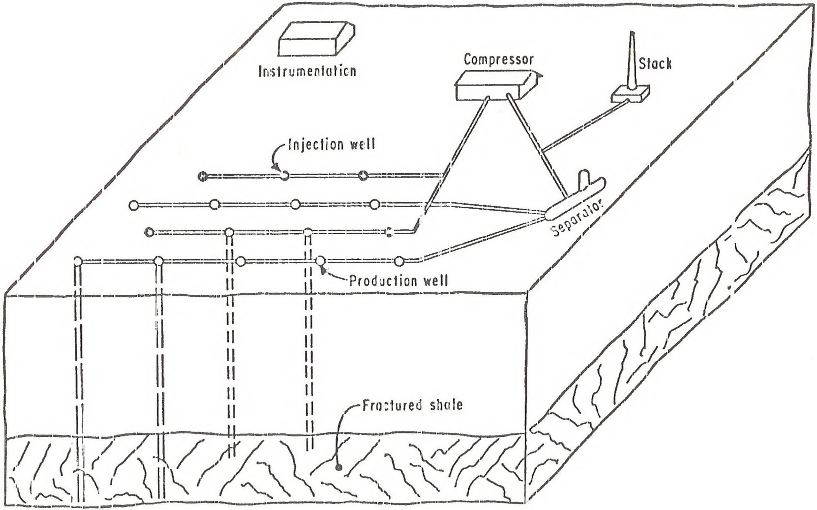


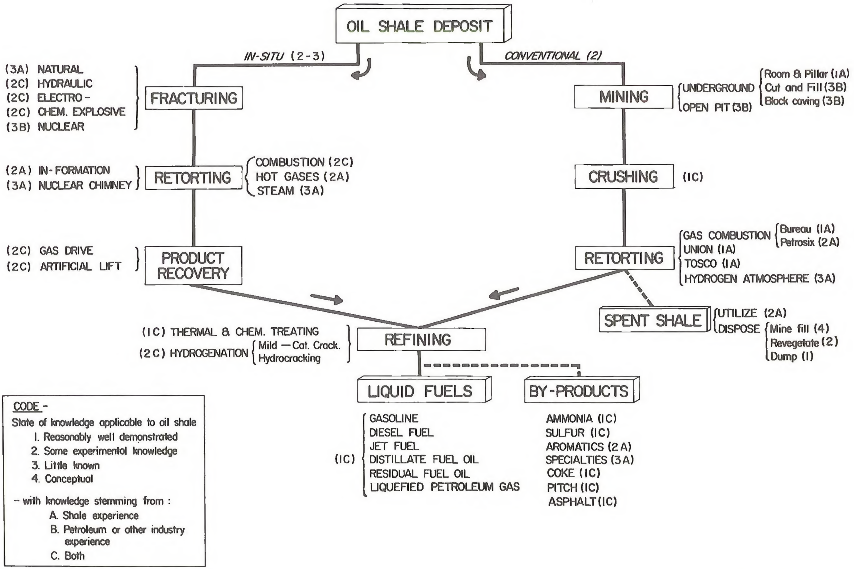
Figure B-3. - Schematic layout for in situ processing.

at any one time. However, the contamination of underground water could pose a problem, through potential changes in reservoir characteristics (e.g. salinity, radioactivity, permeability). These changes cannot be fully determined before exploration and testing.

III. State of Technical Knowledge

A comparison of the relative state of knowledge of the various operations required in oil shale processing by either conventional or in situ processing is shown in figure B-4. The technology is more highly developed for conventional surface processing. A number of the steps suggested for in situ processing are practiced in petroleum recovery, but these have been tested to only a limited extent with oil shale.

Figure B-4. - Oil Shale Utilization - Routes and State of Knowledge



CODE -

State of knowledge applicable to oil shale
1. Reasonably well demonstrated
2. Some experimental knowledge
3. Little known
4. Conceptual

- with knowledge stemming from :
A. Shale experience
B. Petroleum or other industry experience
C. Both

APPENDIX C

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